

APA-24 Low Boom CFD and Experimental Results

*Near-Field Pressure Measurement
of Several Models
in JAXA's 1m x 1m Supersonic Wind Tunnel*

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Outline

- Supersonic Research Program at JAXA
- Objectives
- Supersonic Wind Tunnel Test in 2011
- Supersonic Wind Tunnel Test in 2012
- Summary

Supersonic Research Program at JAXA

National EXp. Supersonic Transport Program

NEXST program

Silent Supersonic Tech. Research Program

S-cube Program

Year

1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014~

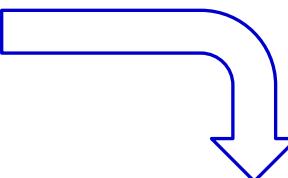
Design concept

- Cranked arrow wing
- Warp airfoil
- Area-ruled fuselage
- Natural Laminar flow

Design tools

- Carlson warp
- CFD-based inverse design

Flight demo.



Design concept

- Non-axisymmetric nose
 - Lifting aft-fuselage
 - Inversely cambered stabilizer
- Design tools
- CFD-based optimization
 - MDO

Flight demo.

Phase 1 (D-SEND) Phase 2 (S3TD)

D-SEND#1

D-SEND#2

S3TD



NEXST-1



Non-powered
Rocket-boosted



Non-powered
Balloon drop



Jet-powered
Takeoff/Land

Low-drag tech. R&D

Low-sonic-boom tech. R&D

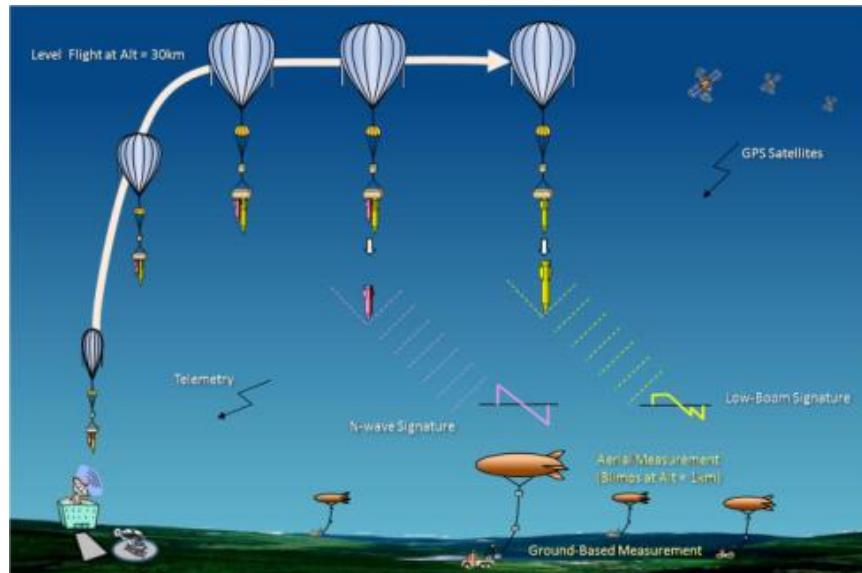
“D-SEND” Project

p.4

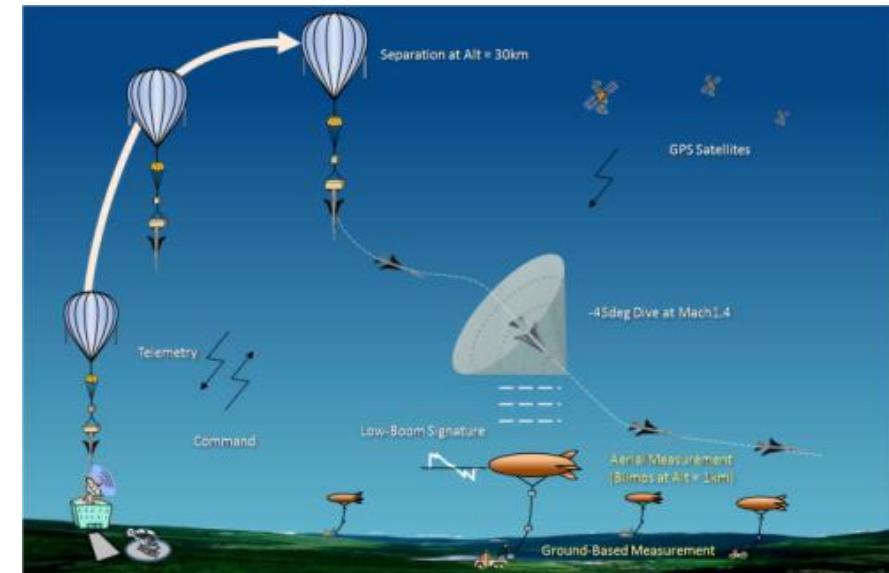
Drop test for Simplified Evaluation of Non-symmetrically Distributed sonic boom

- Objective

- To validate JAXA’s low-boom design concepts.
- To establish airborne sonic boom measurement system.

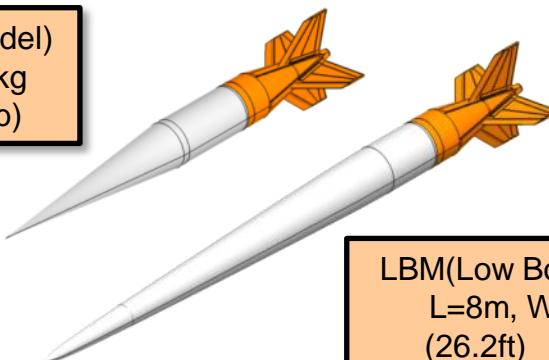


D-SEND#1 (2011.05)



D-SEND#2 (2013)

NWM(N Wave Model)
L=5.6m, W=700kg
(18.4ft) (1.5kib)



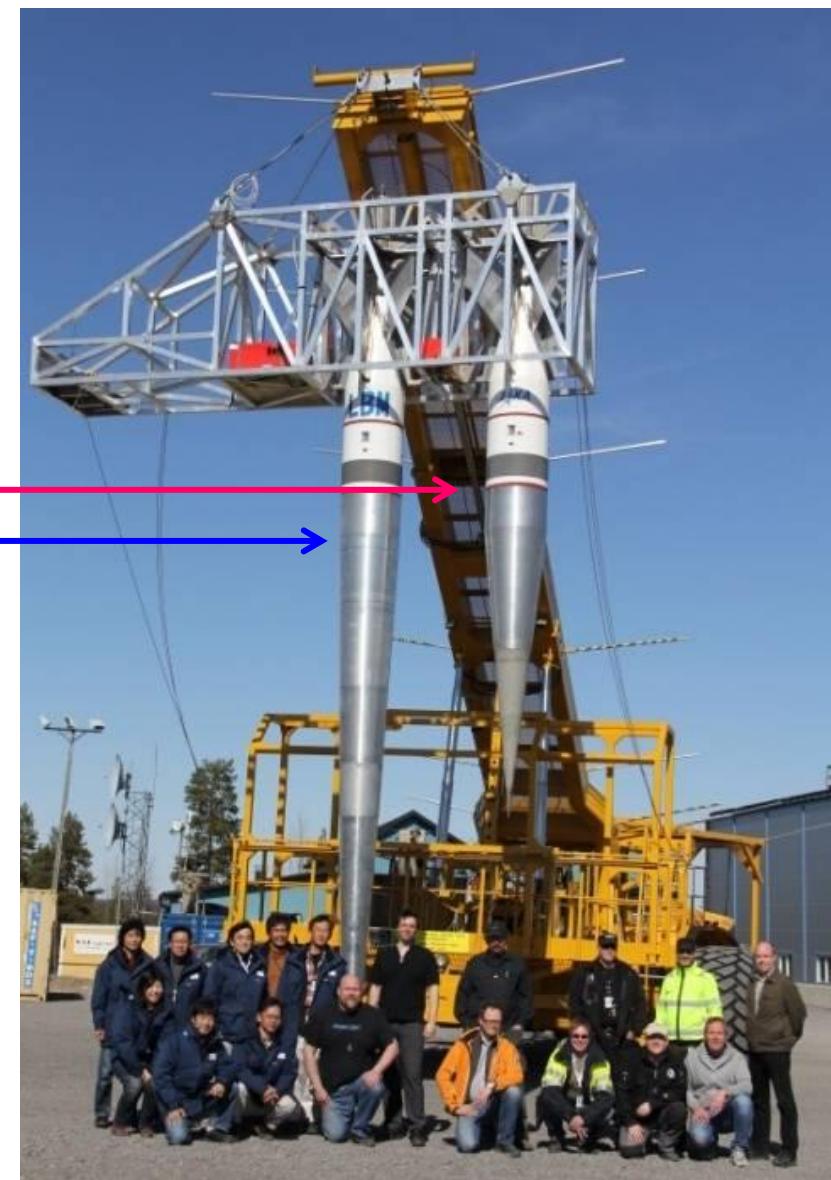
LBM(Low Boom Model)
L=8m, W=630kg
(26.2ft) (1.4kib)



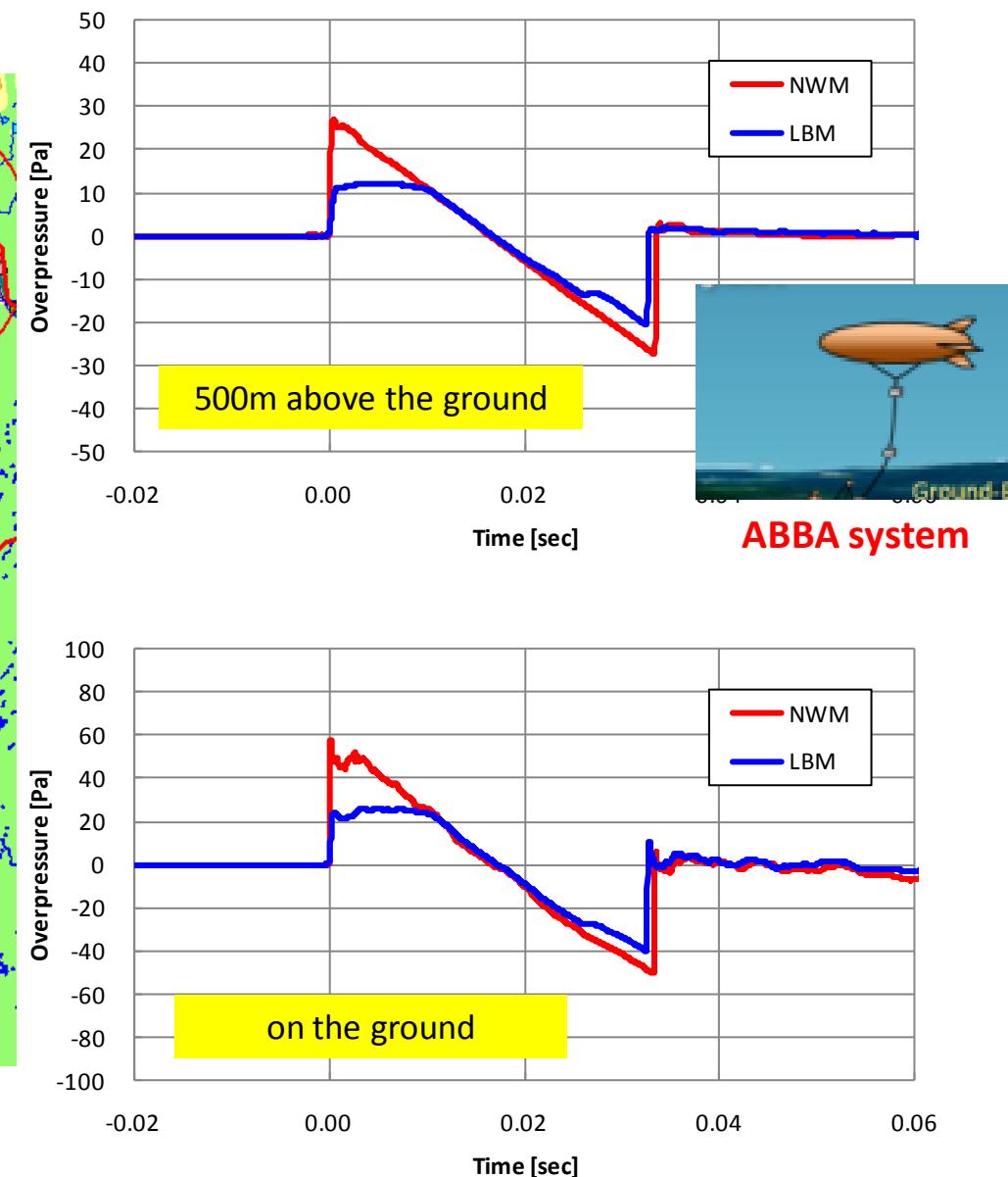
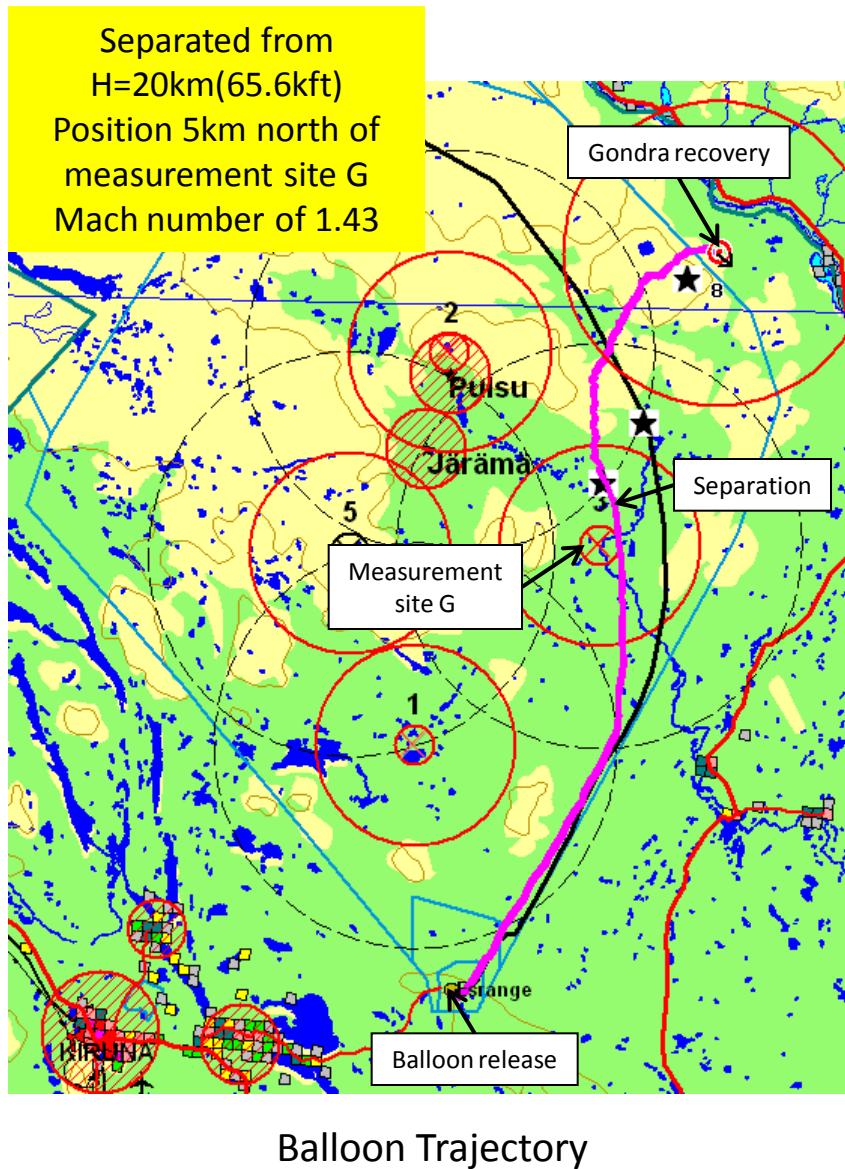
S3CM(S-cube Concept Model)
L=7.7m, W=1000kg
(25.3ft) (2.2kib)

D-SEND#1

- Objectives
 - To validate the low-boom demonstration technique.
 - To establish airborne boom measurement system.
- Overview
 - Date: May 7th and 16th, 2011
 - Place: Sweden (NEAT)
 - # of Drop Tests: 2
 - # of Drop Bodies: 2 in each test
 - N-Wave Model (NWM) 
 - Low-Boom Model (LBM) 



D-SEND#1 1st Drop Test



D-SEND Database



Drop test for Simplified Evaluation of Non-symmetrically Distributed sonic boom

[Japanese](#) / [English](#)



[HOME](#) [About D-SEND](#) [D-SEND#1](#) [D-SEND#2](#) [ABBA Test](#) [Contact](#)

D-SEND Experimental Data



D-SEND#1

- To acquire the airborne boom measurement technique.
- To make sure the possibility of the low-sonic-boom design concept validation with a scaled model.
- To prepare the D-SEND#2 flight test (Test protocol and measurement system check)



D-SEND#2

- To demonstrate both front and rear shock shaping design.
- To acquire the low-boom sonic-boom signature measurement technique.
- To obtain the validation data for low-boom sonic-boom signature propagation tools.



ABBA Test

- To establish sonic-boom measurement technique (airborne, on the ground).
- To gather the data for sonic-boom evaluation.
- To make sure the validity of the flight test in the D-SEND project.
- To obtain the validation data for sonic-boom prediction method.

http://d-send.jaxa.jp/d_send_e/index.html

[HOME](#) [About D-SEND](#) [D-SEND#1](#) [D-SEND#2](#) [ABBA Test](#) [Contact](#)

HOME > D-SEND#1

D-SEND#1

D-SEND#1 Overview

JAXA conducted the D-SEND#1 drop tests on May 7th and 16th in 2011 at Esrange test range in Sweden supported by the Swedish Space Corporation(SSC). The low sonic-boom design results have been validated with an axisymmetric body for the first time.

The D-SEND Database provides the geometries of two D-SEND#1 models named NWM(N-wave Model) and LBM(Low-Boom Model) as well as these drop profile data and sonic boom data obtained in both drop tests.

Data Download

D-SEND#1

Model Geometries

- [NWM/LBM configuration data \(D-SEND#1 Model.lzh\)](#)

1st Drop Test

- [Drop profile/Weather data \(D-SEND#1-1 PathWeather.lzh\)](#)

Sonic-boom data

- [\(D-SEND#1-1 Boom.lzh\)](#)

2nd Drop Test

- [Drop profile/Weather data \(D-SEND#1-2 PathWeather.lzh\)](#)

Sonic-boom data

- [\(D-SEND#1-2 Boom.lzh\)](#)

	1st Drop Test	2nd Drop Test
Balloon Release Time	AM5:44 7th May,2011 LT	AM5:30 16th May,2011 LT
Separation Time	AM7:02 7th May,2011 LT	AM7:36 16th May,2011 LT
Separation Altitude	About 21km	About 27km
Maximum Mach Number	About M=1.4	About M=1.7

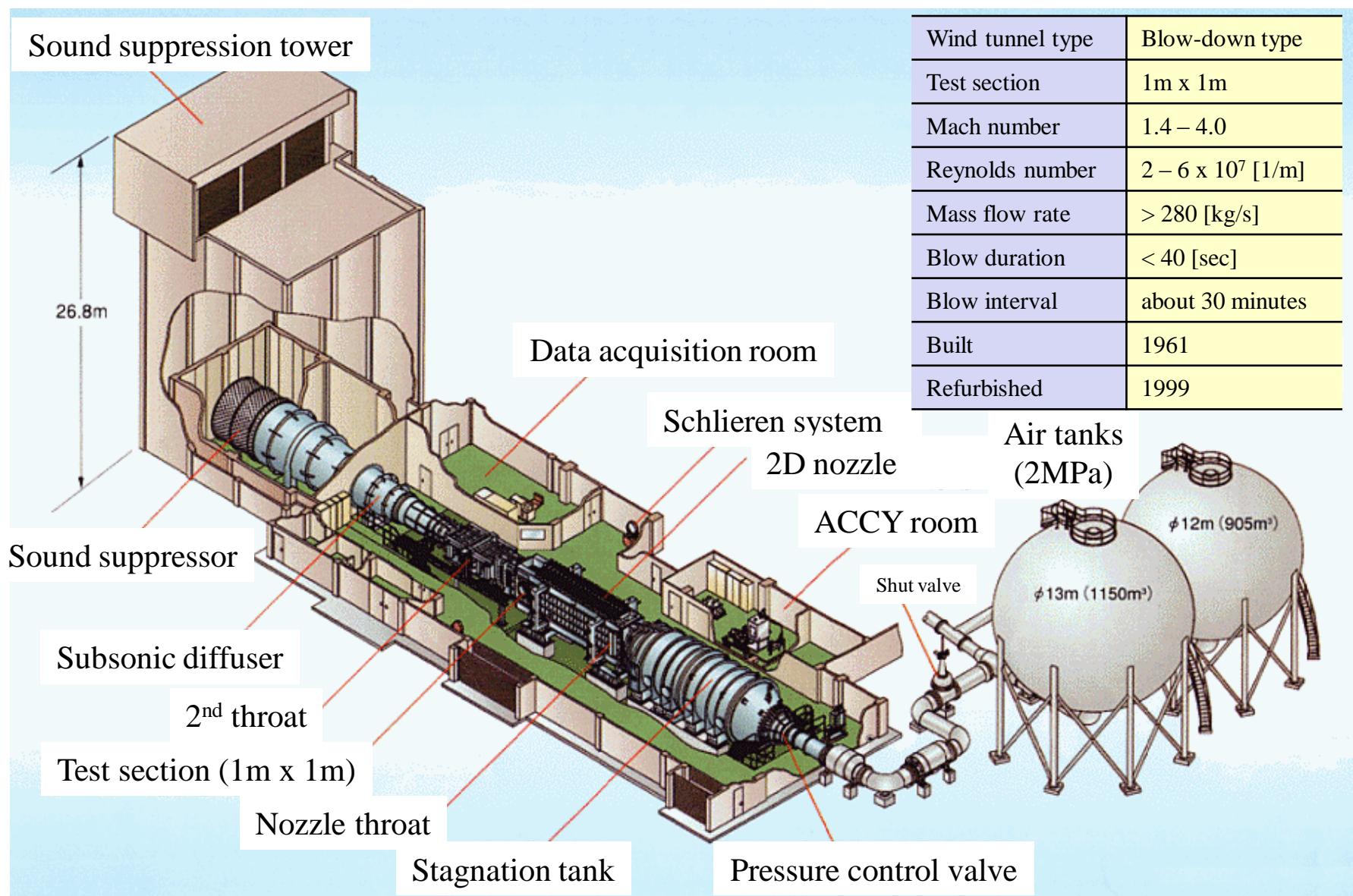
1st Drop Test

2nd Drop Test

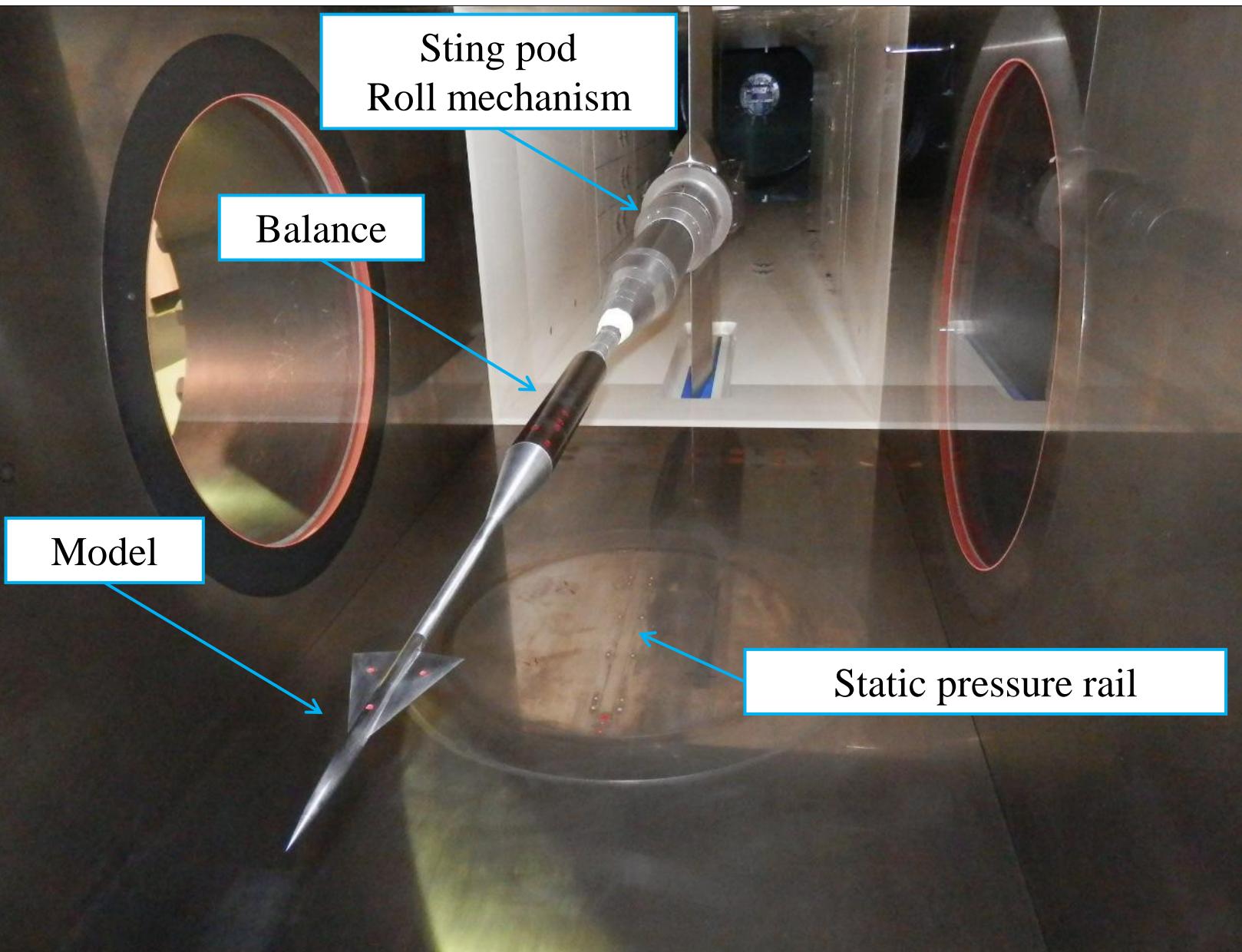
Objectives

- To obtain validation data for sonic-boom prediction tools.
 - Simple body of revolution models.
 - 69-degree swept-back angle delta wing body model.
(for 1st Low Boom Workshop)

1m x 1m Supersonic Wind Tunnel (JSWT)



Test Apparatus



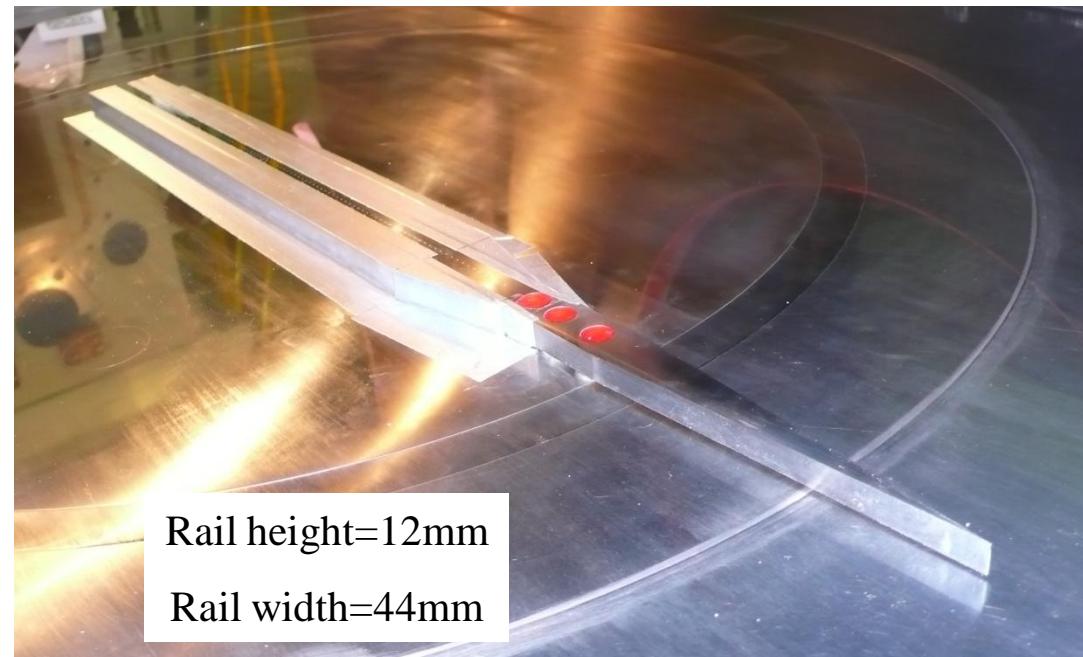
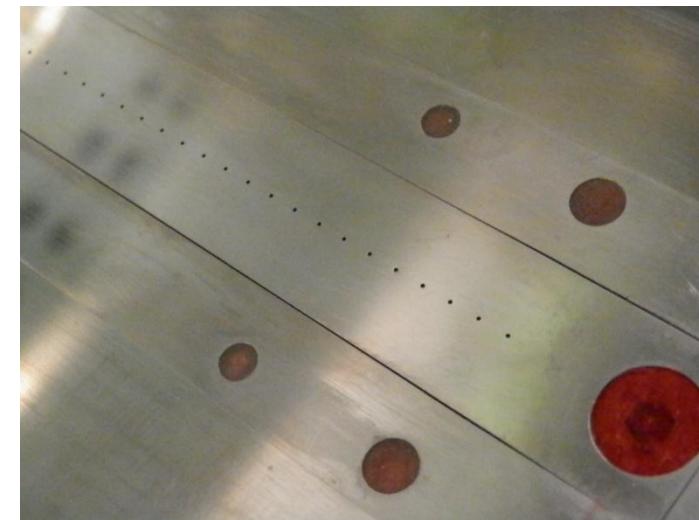
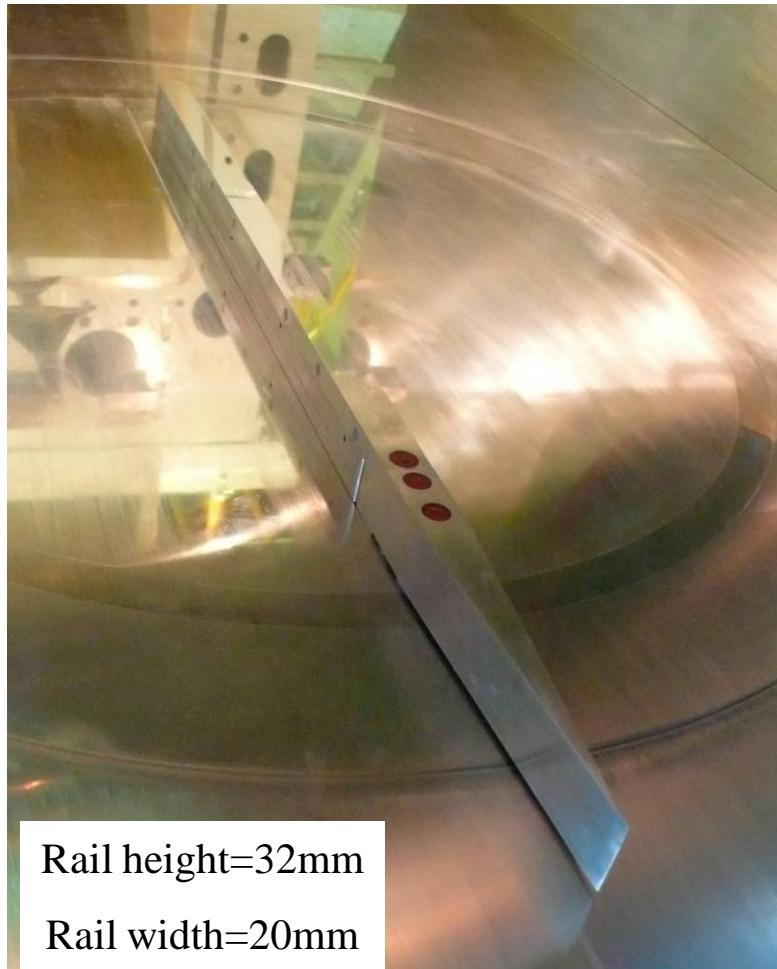
Static Pressure Rail

Length=450mm, Width=20, 44mm

Height=0, 12, 32, 52mm

111points pressure taps

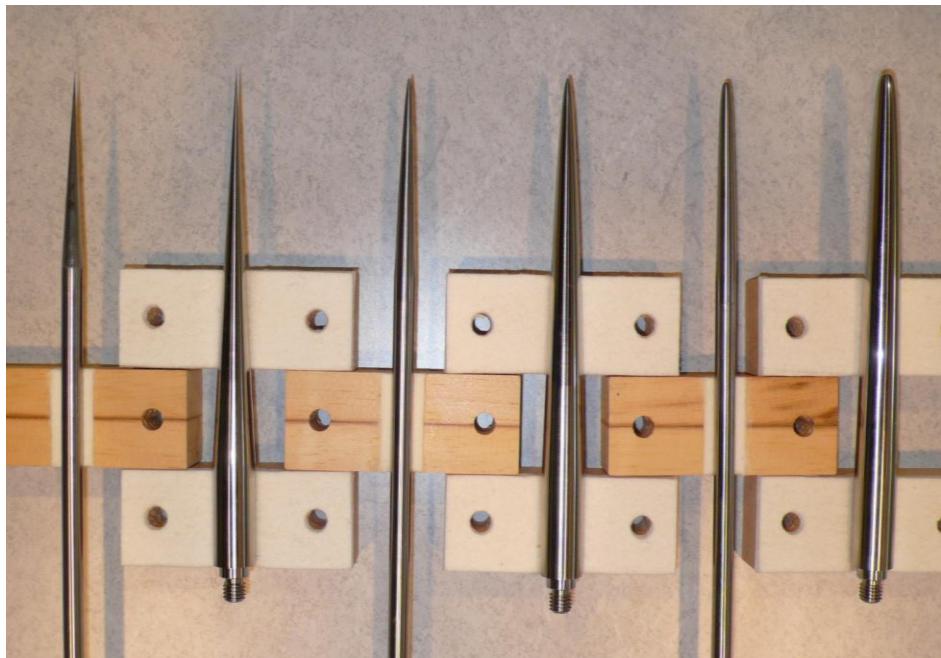
(4mm interval, 440mm measurement region)



Test Models

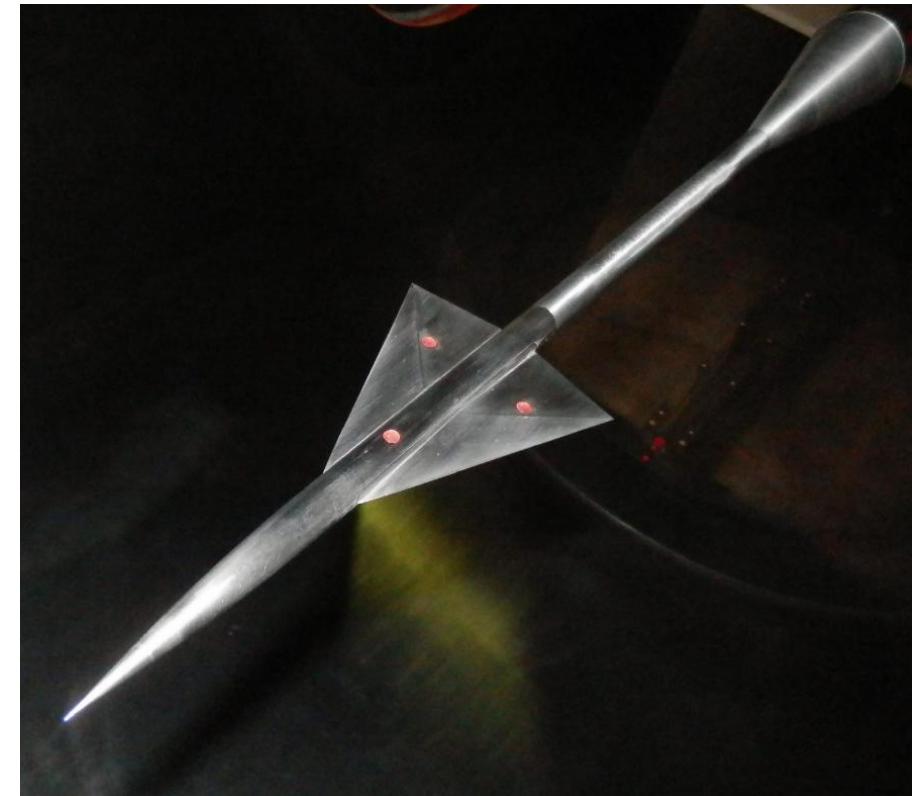
Axisymmetrical models

<u>Cone</u>	<u>Parabolic</u>	<u>Quartic</u>
80mm	160mm	80mm



cf. NASA TN D-3160

69-degree swept-back delta wing body model



cf. NASA TN D-7160

Supersonic Wind Tunnel Test in 2011

2011/5/23~6/3

< Axisymmetrical models >

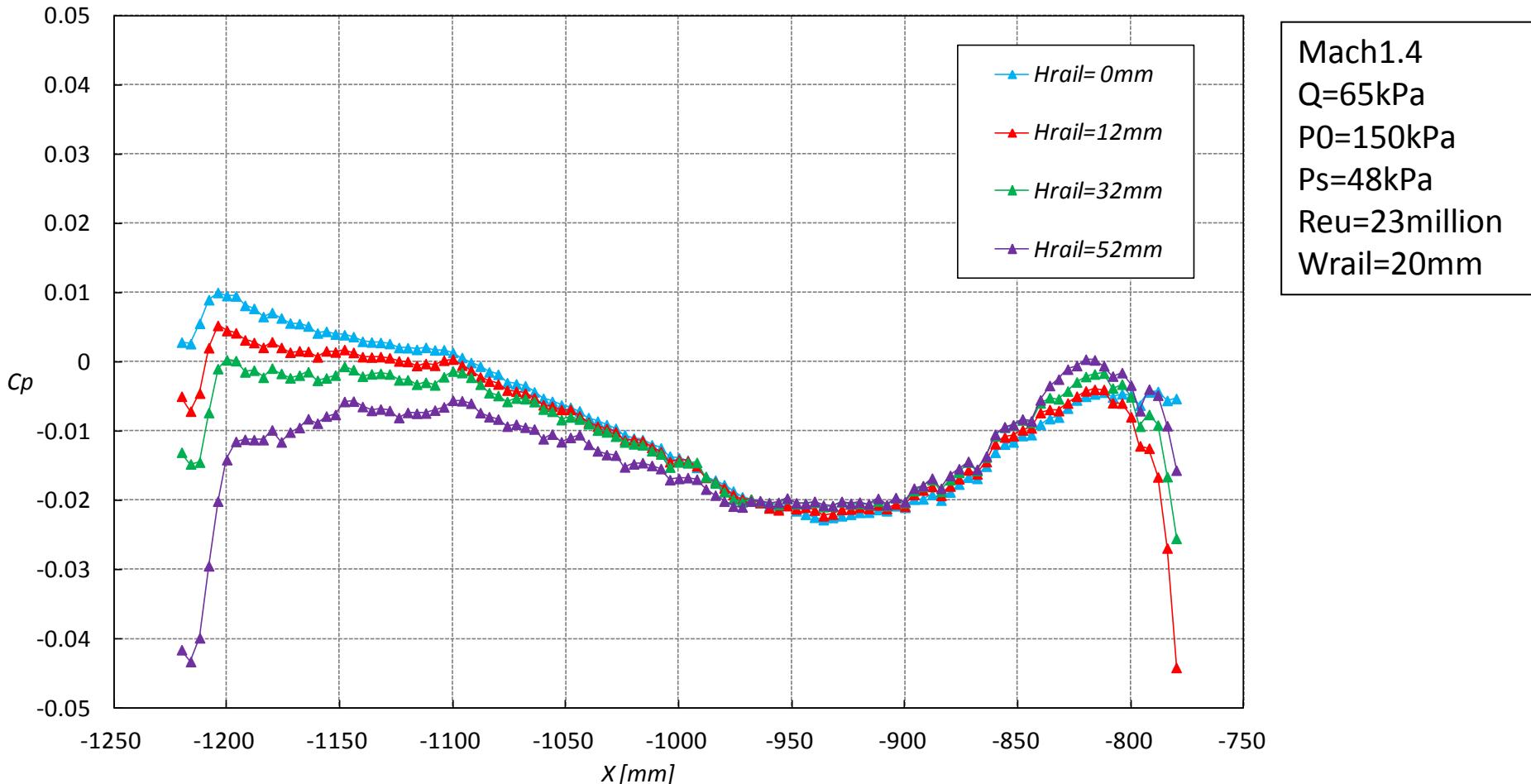
- *To investigate rail height effects*

< 69-degree delta wing body model >

- *To obtain rail data at AoA=0deg (w/o balance)*

Pressure Distribution on the Pressure Rail

p.14



- Some pressure changes are shown on the wind-tunnel wall even without the model.
- The pressure variation gets larger as the rail height increases.

Model On/Off Correction

Parabolic model

$M=1.4$

$\alpha=0\text{deg}$

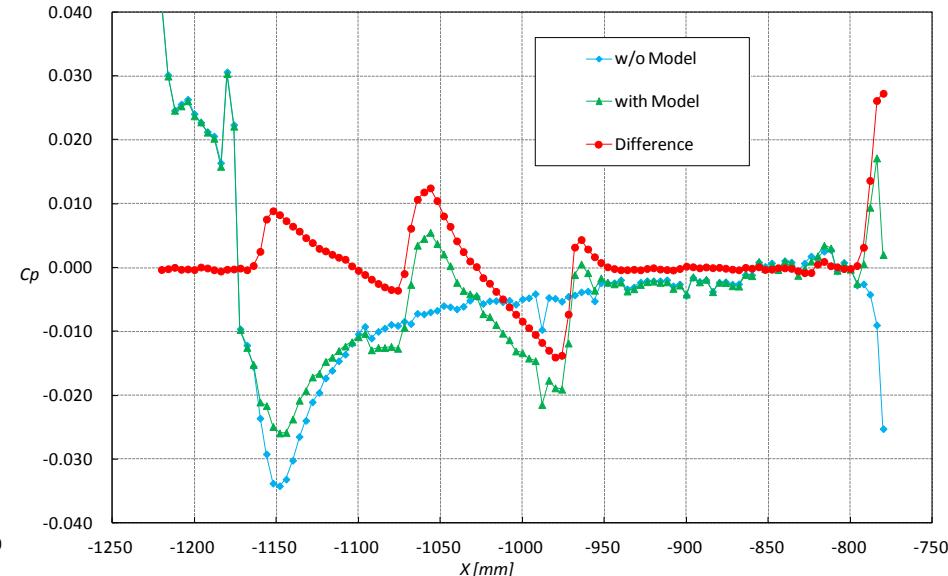
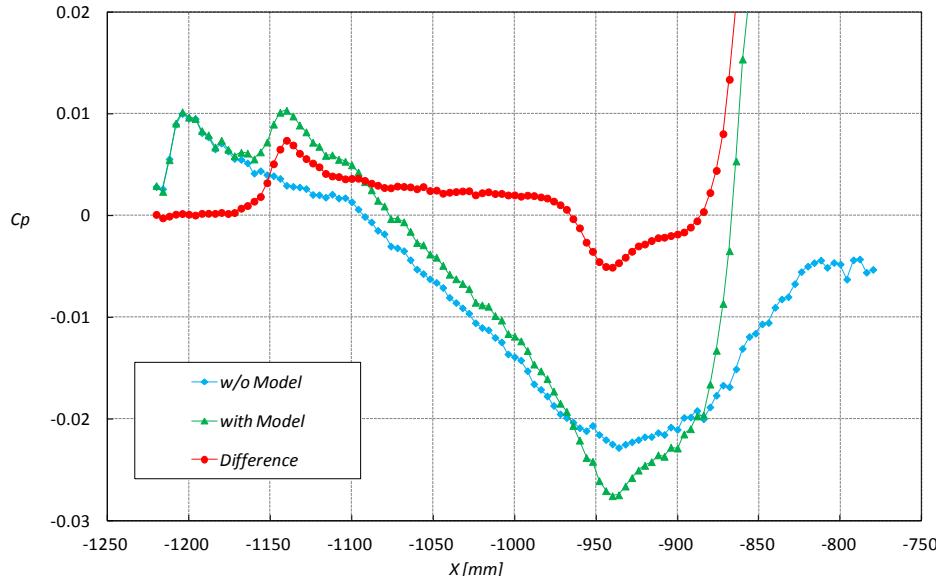
$H_{rail}=0\text{mm}, W_{rail}=20\text{mm}$

69-degree delta wing body model

$M=1.68$

$\alpha=0\text{deg}$

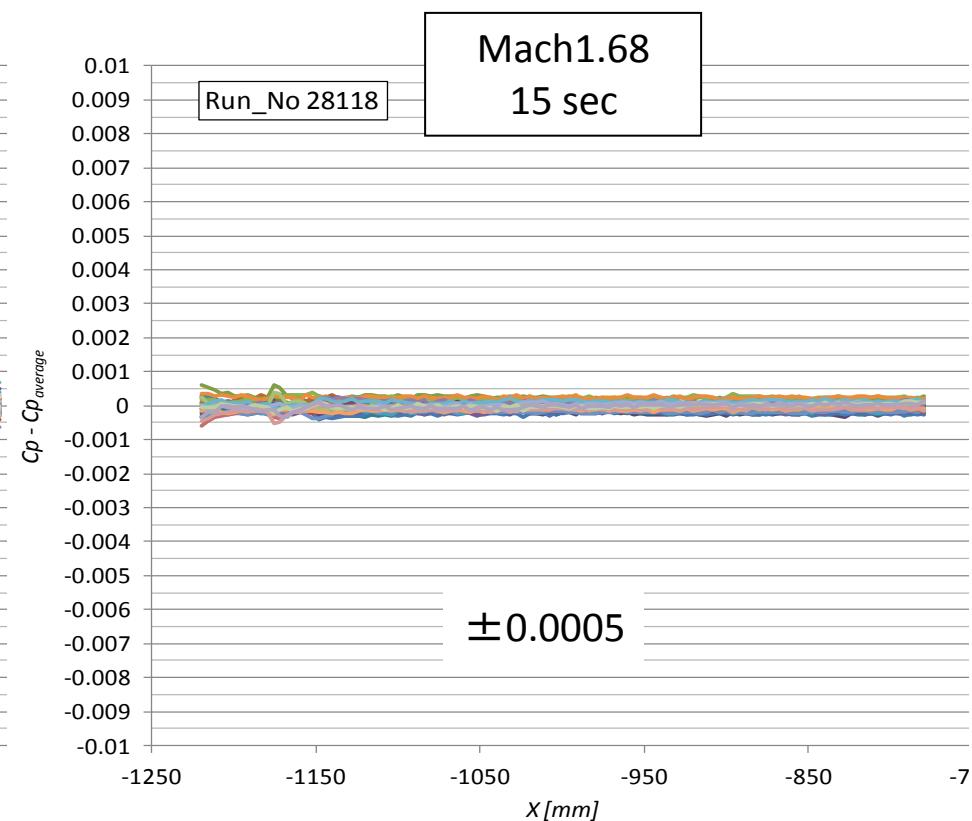
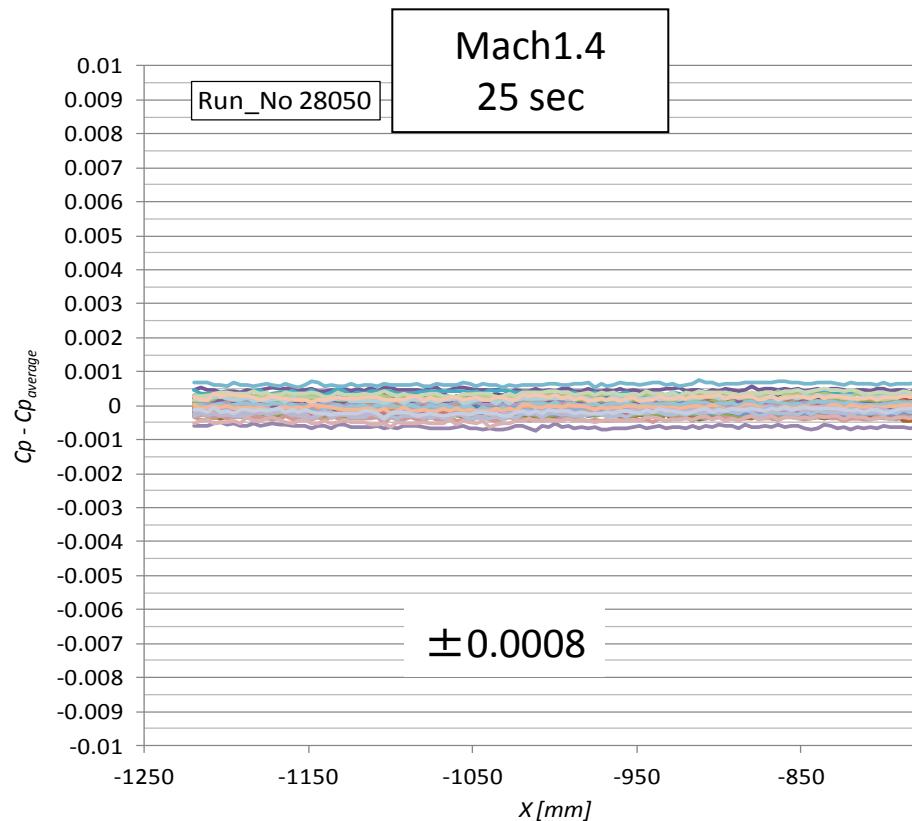
$H_{rail}=12\text{mm}, W_{rail}=44\text{mm}$



- The result that C_p differences at front part of the signatures are almost zero shows the model on/off correction works well in the test.

Pressure Variation(Model Off Case)

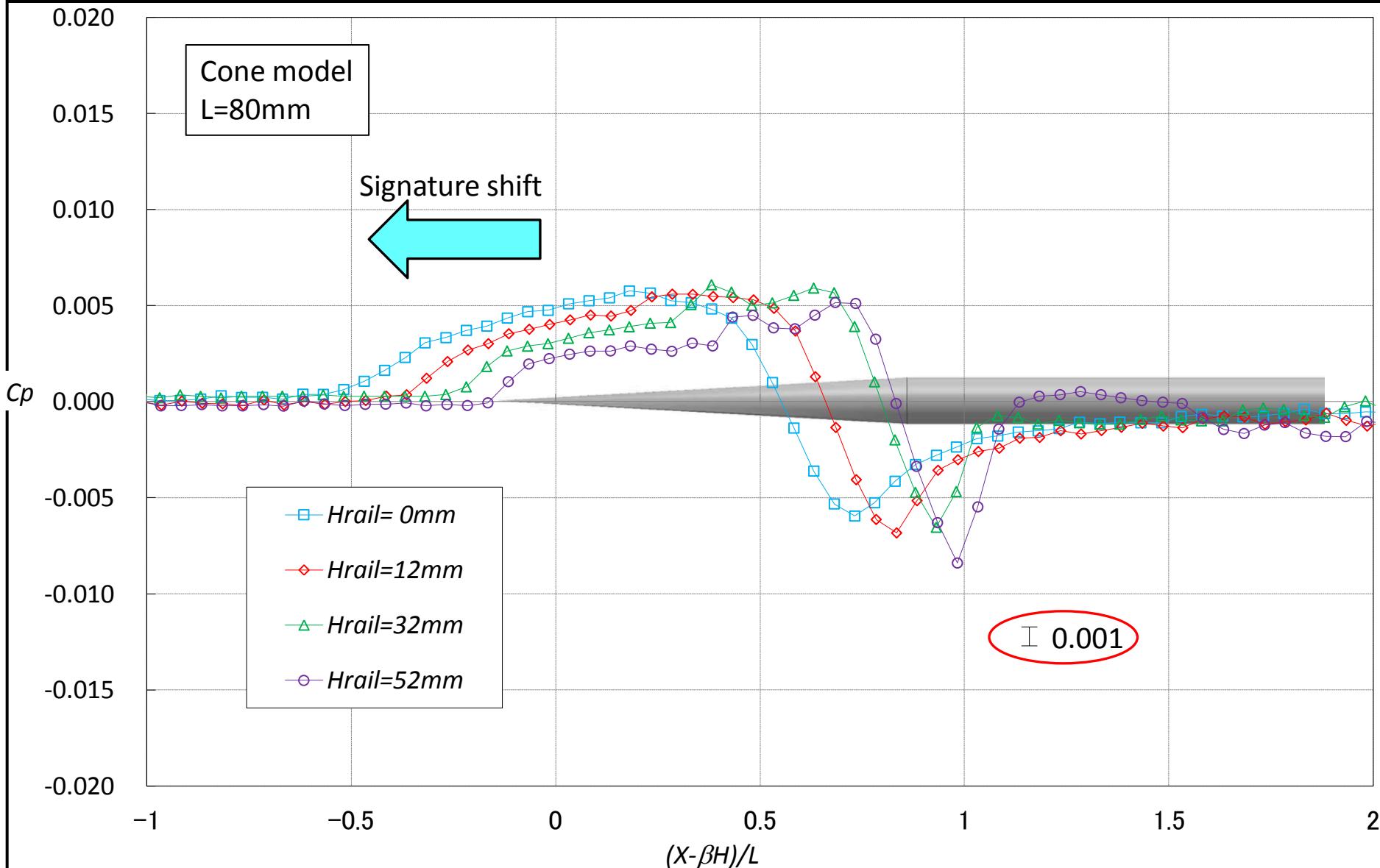
Deviation from the average at each point



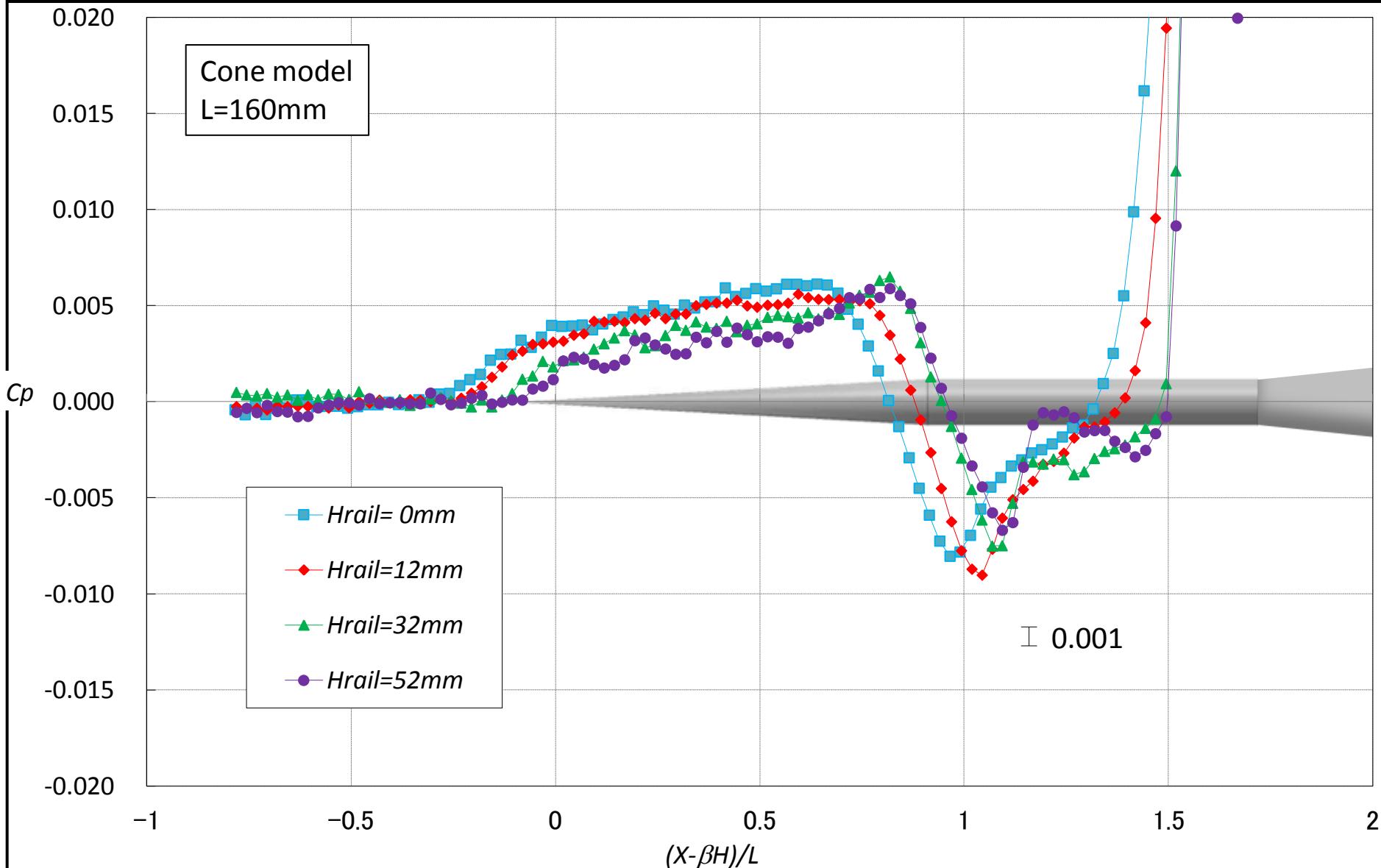
- The C_p standard deviations are about 0.00024 for $M=1.4$ and 0.00018 for $M=1.68$ in C_p .
- The pressure variation is about 50Pa@M1.4, 35Pa@M1.68 while the accuracy of the used pressure transducer(ZOC 15psi module) is about 160Pa.

p.17

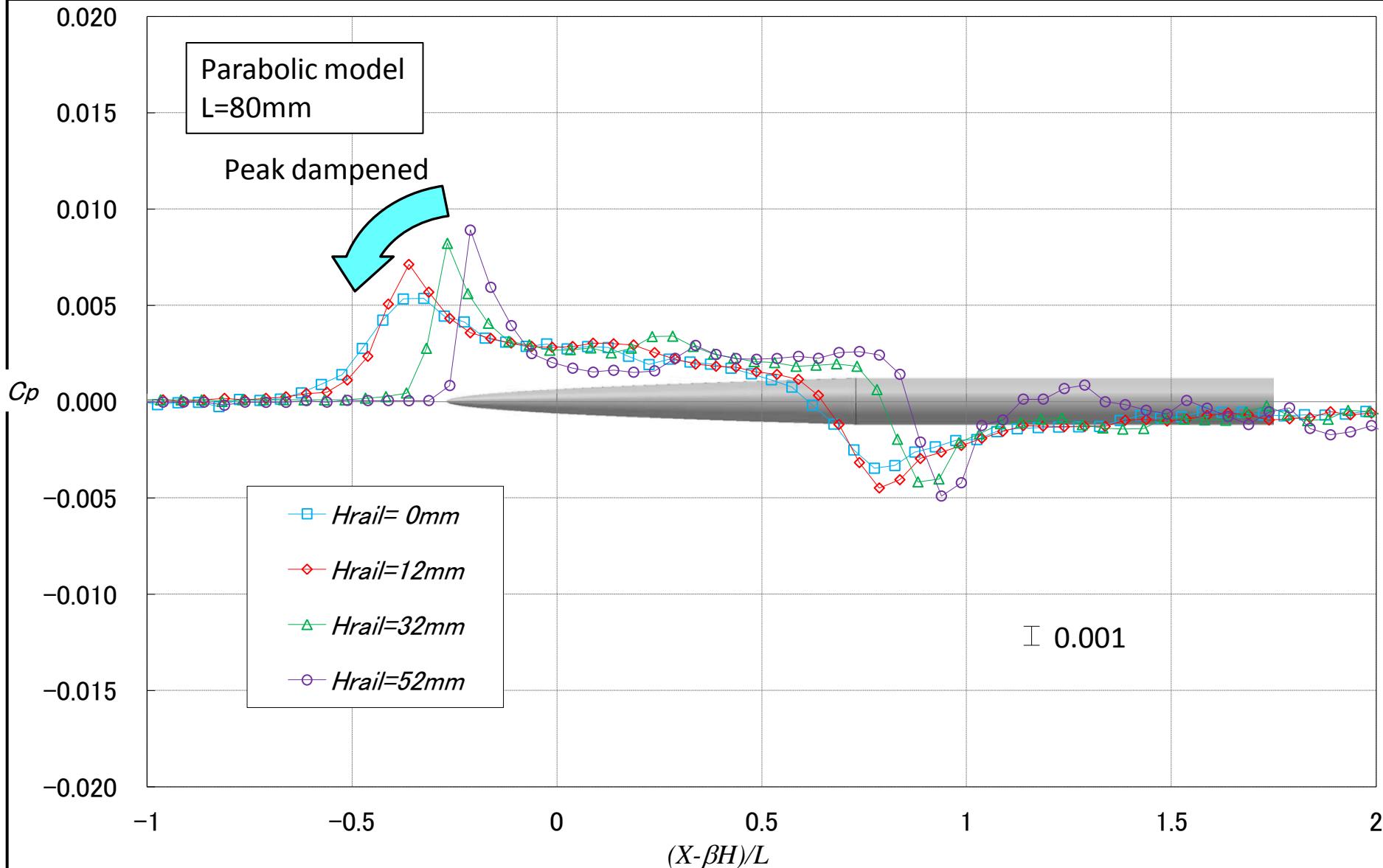
Rail Height Effects



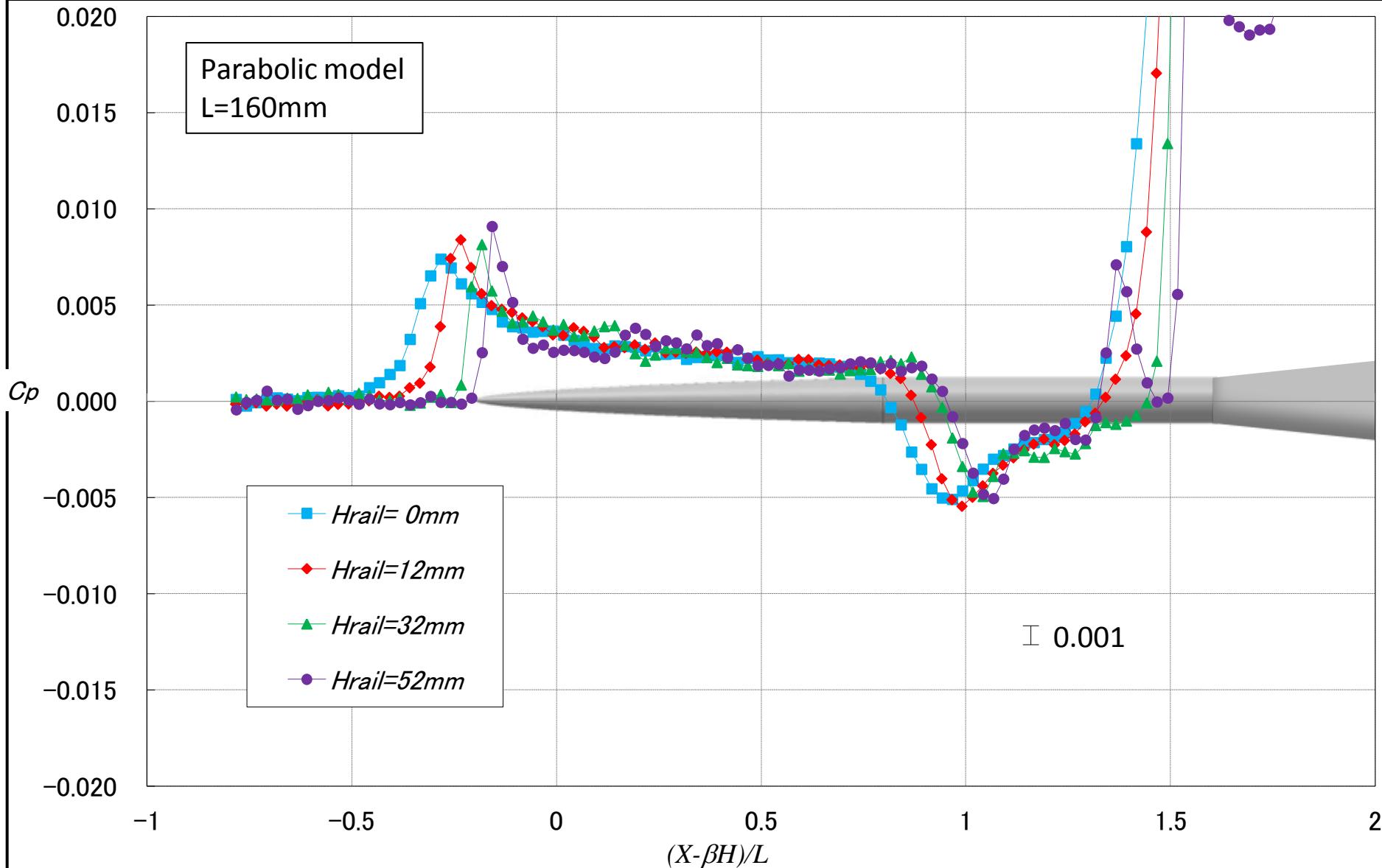
Rail Height Effects



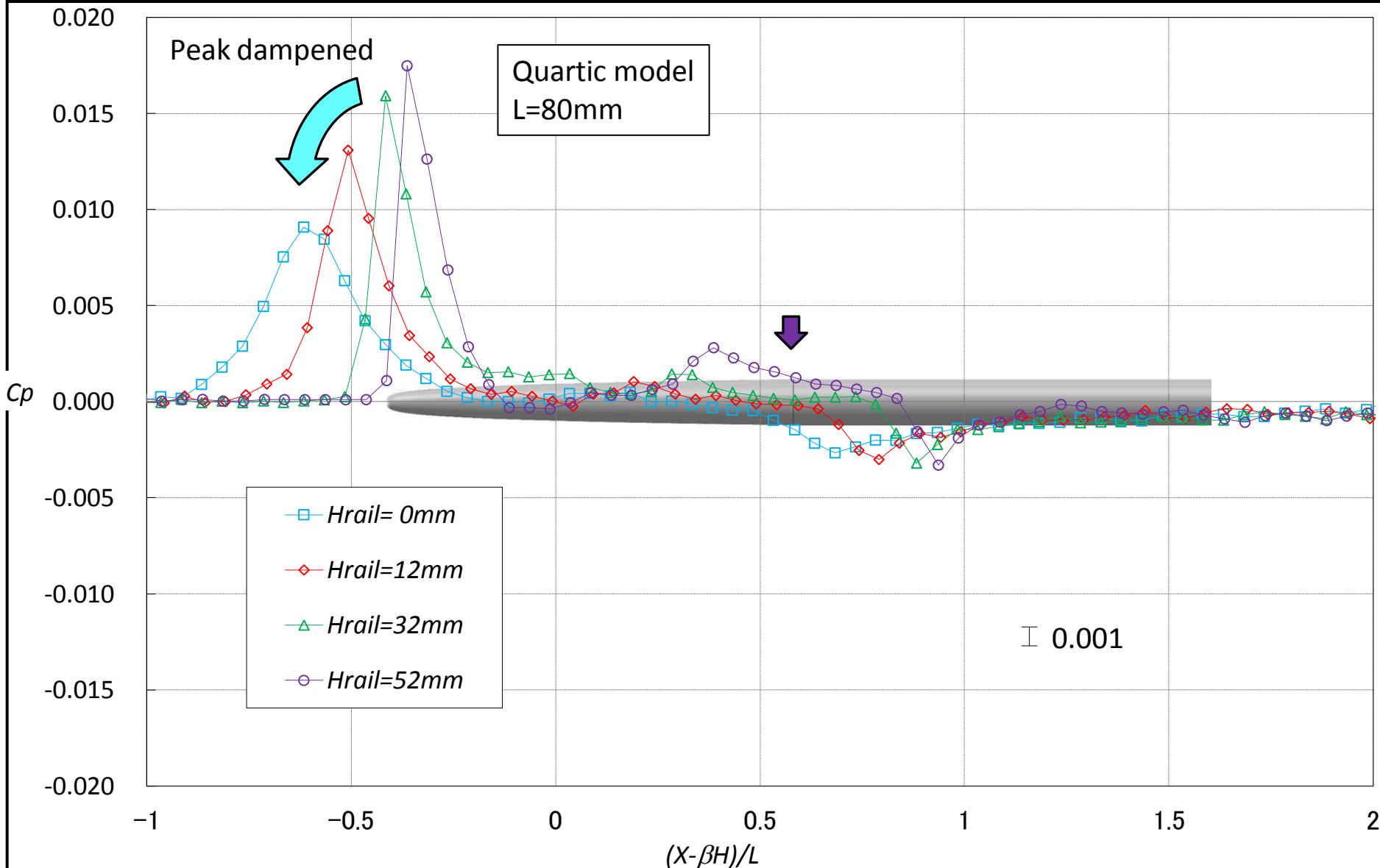
Rail Height Effects



Rail Height Effects

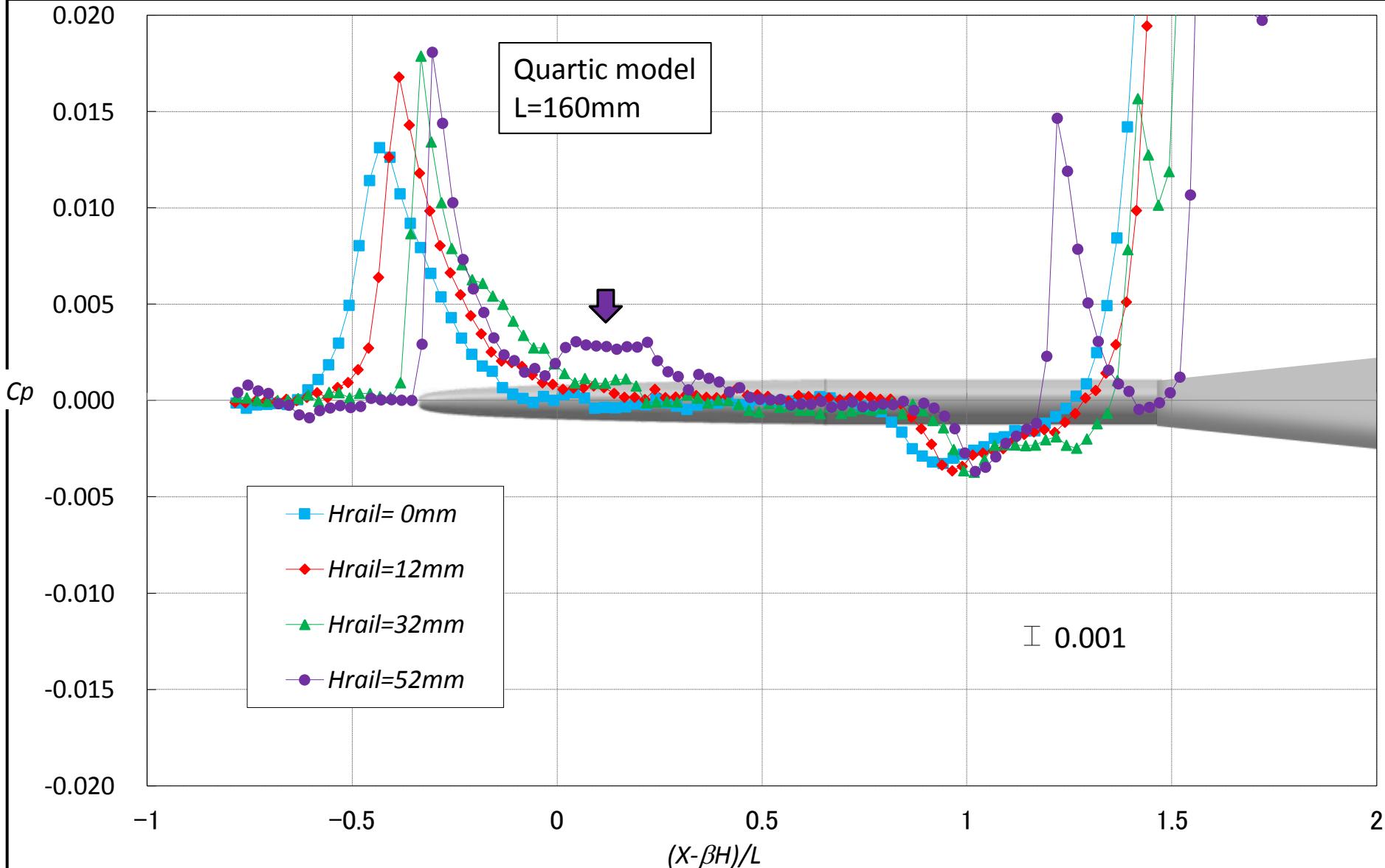


Rail Height Effects

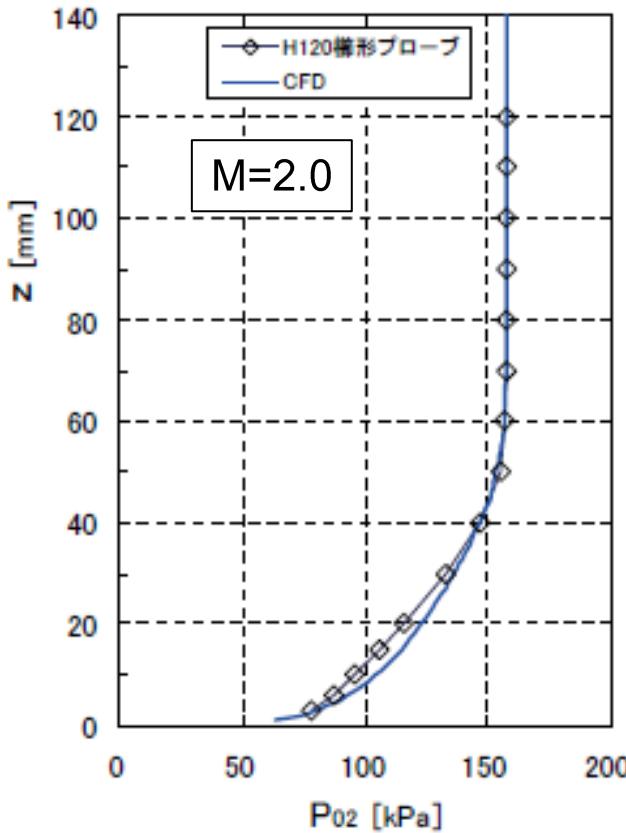


p.22

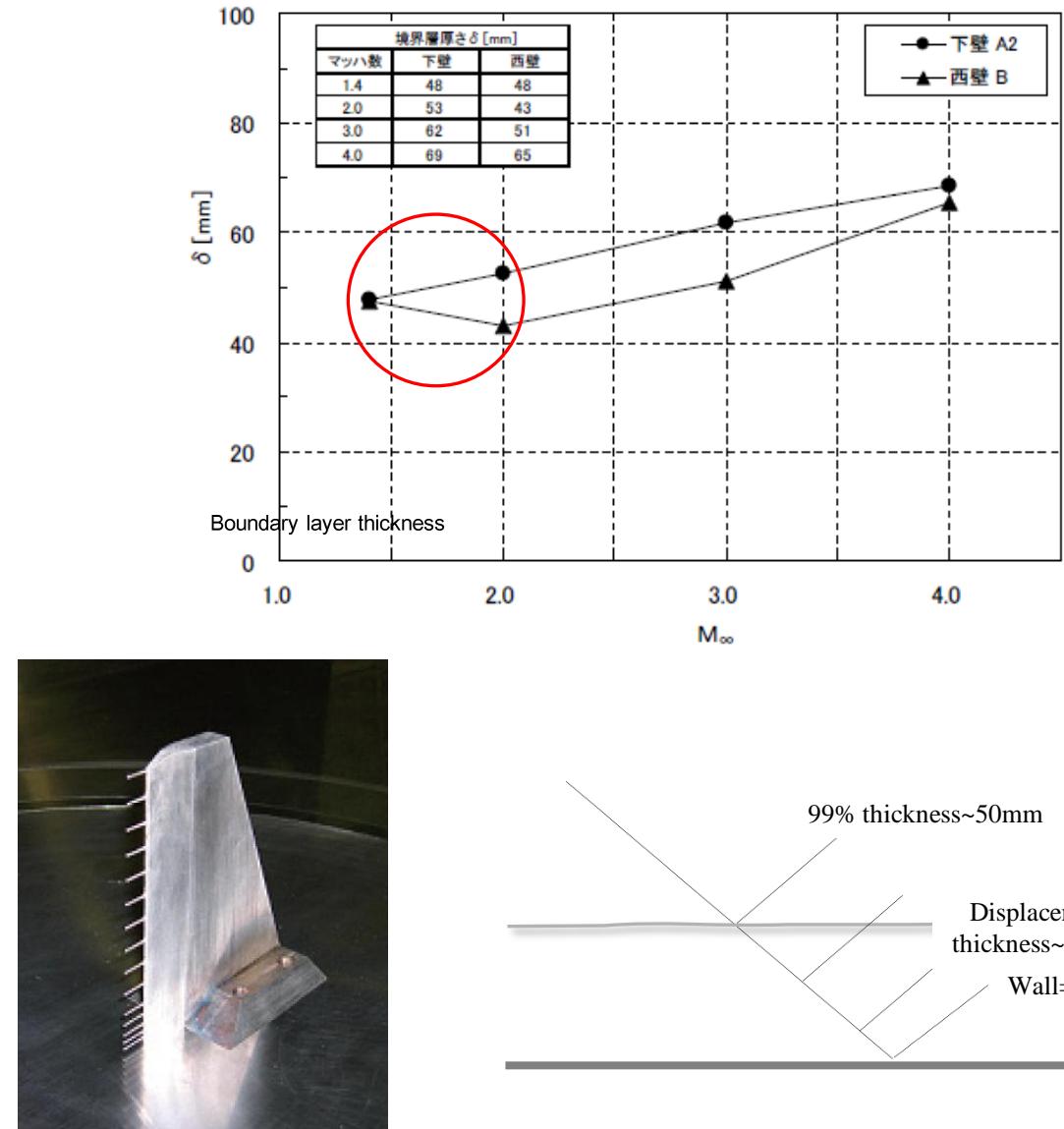
Rail Height Effects



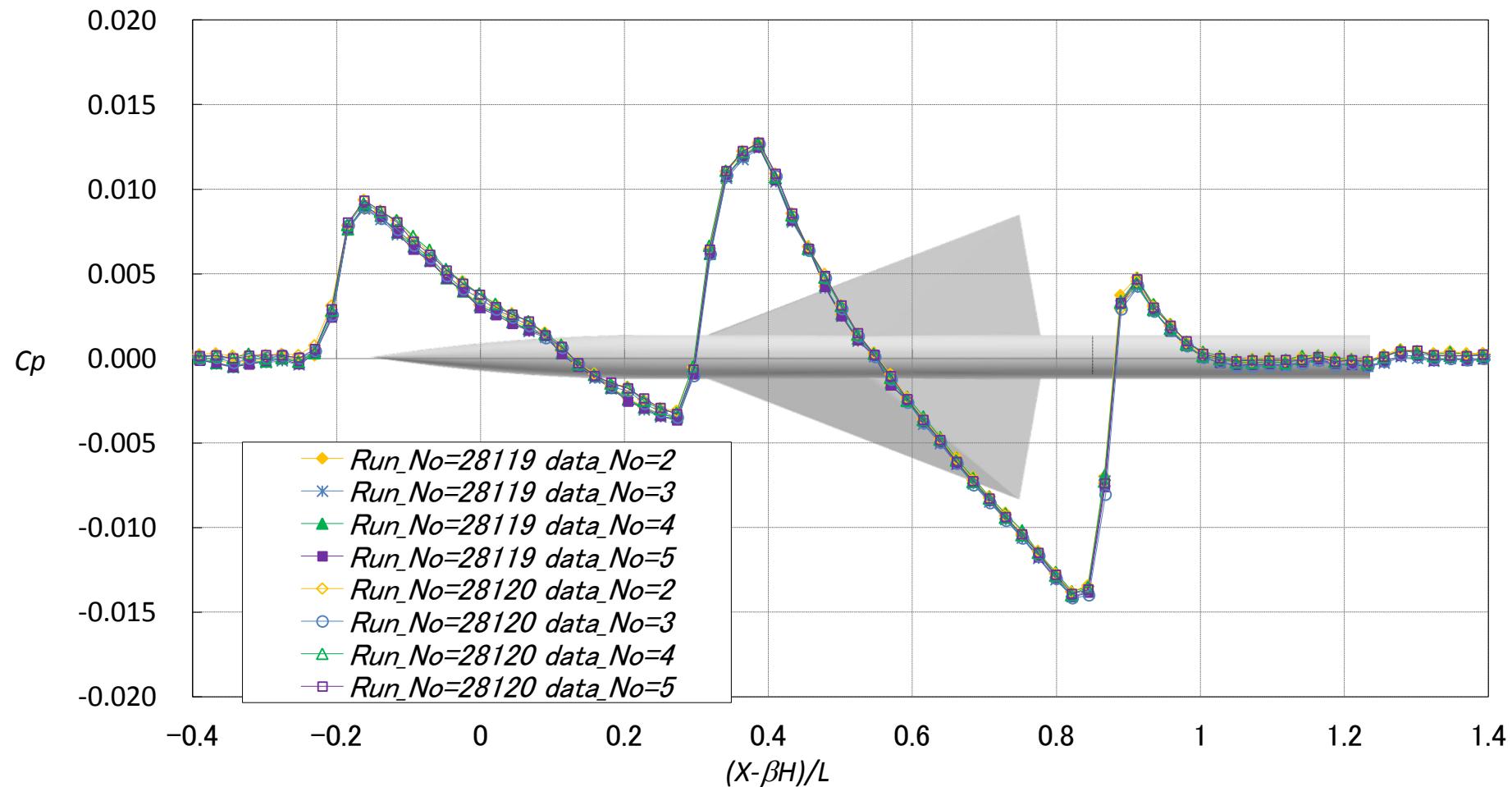
Boundary Layer in J SWT



JAXA-RM-08-011

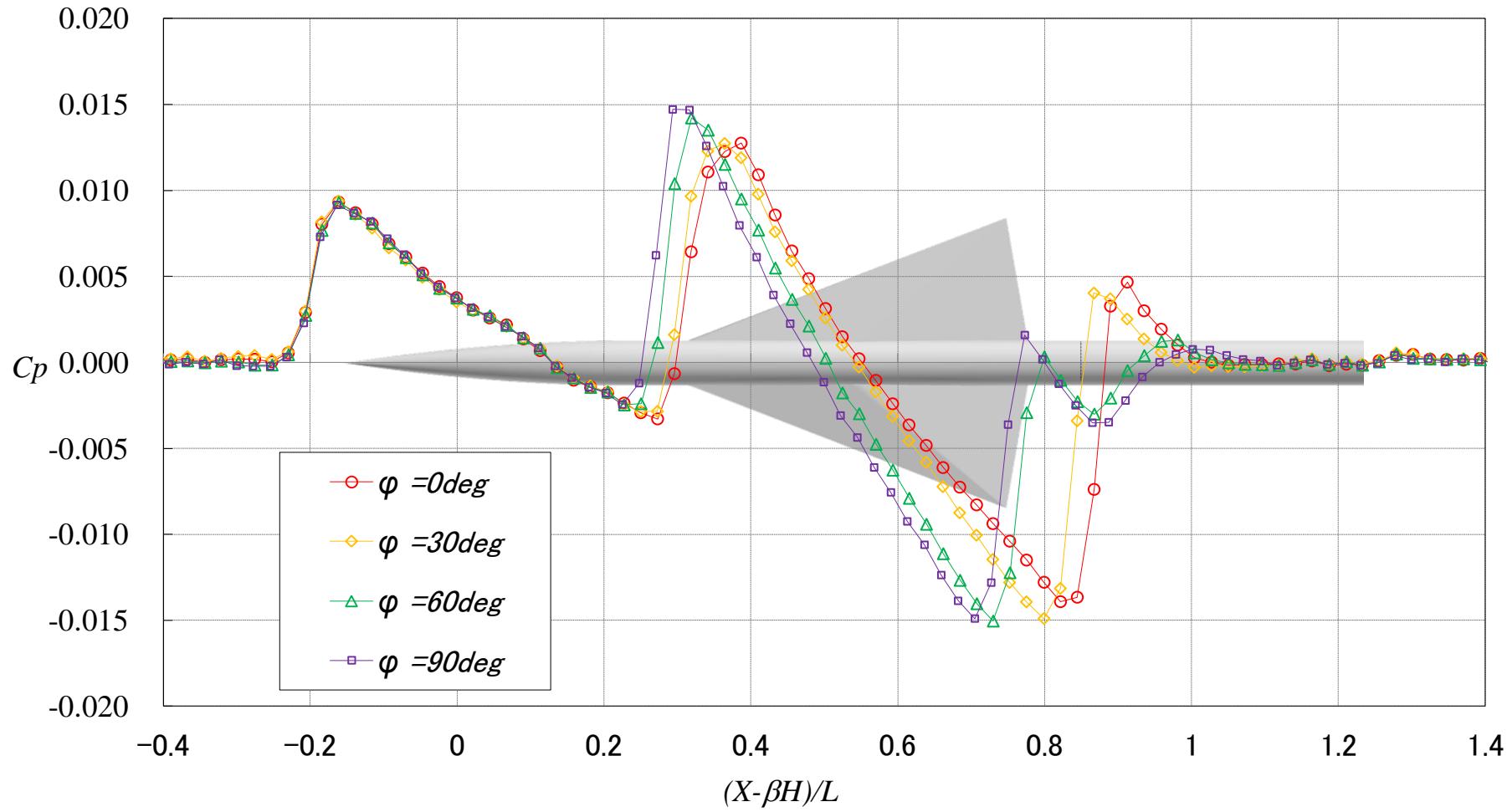


69-degree Delta Wing Body Model



$M=1.68$, $\alpha=0\text{deg}$, $\phi=0\text{deg}$, $H/L=3.6$, $H_{rail}=12\text{mm}$, $W_{rail}=44\text{mm}$

69-degree Delta Wing Body Model



$M=1.68, \alpha=0\text{deg}, H/L=3.6, H_{rail}=12\text{mm}, W_{rail}=44\text{mm}$

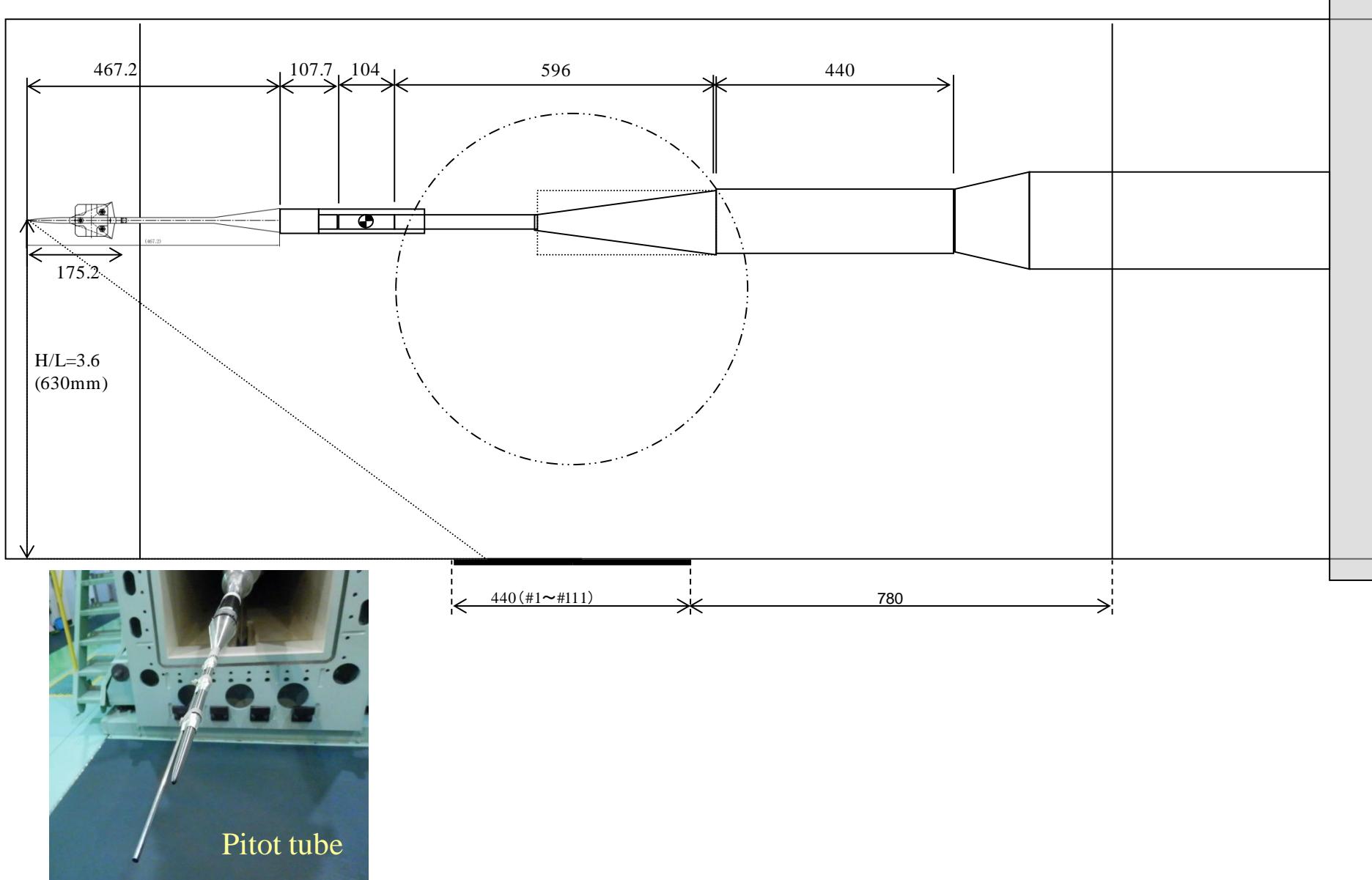
Supersonic Wind Tunnel Test in 2012

2012/12/26~28

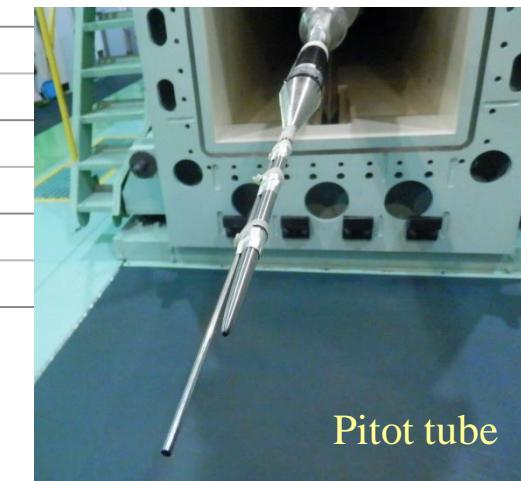
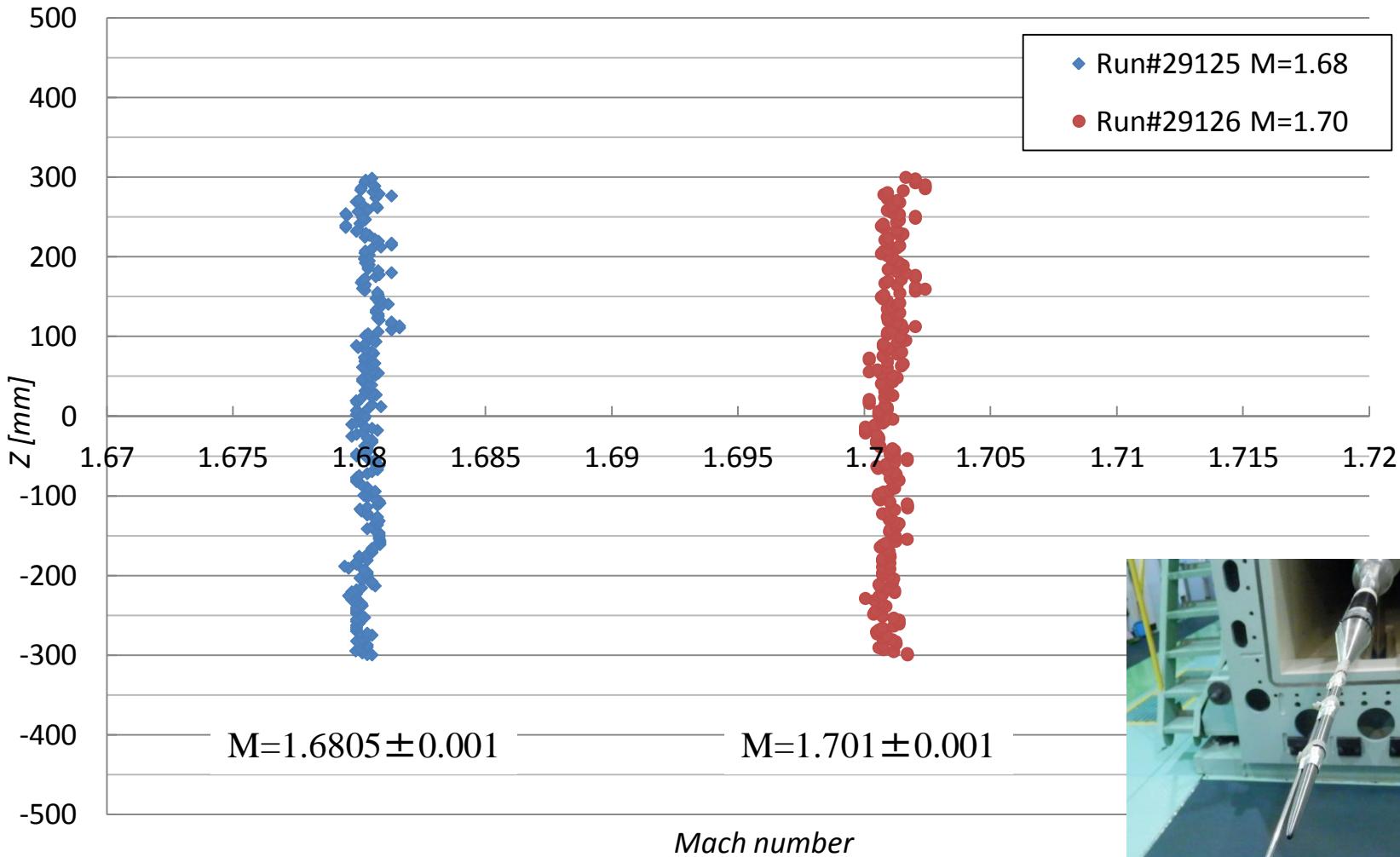
< 69-degree delta wing body model >

- *To obtain rail data at $C_L=0.08, 0.15$ (with balance)*
- *To check Mach number distribution*
- *To check repeatability*

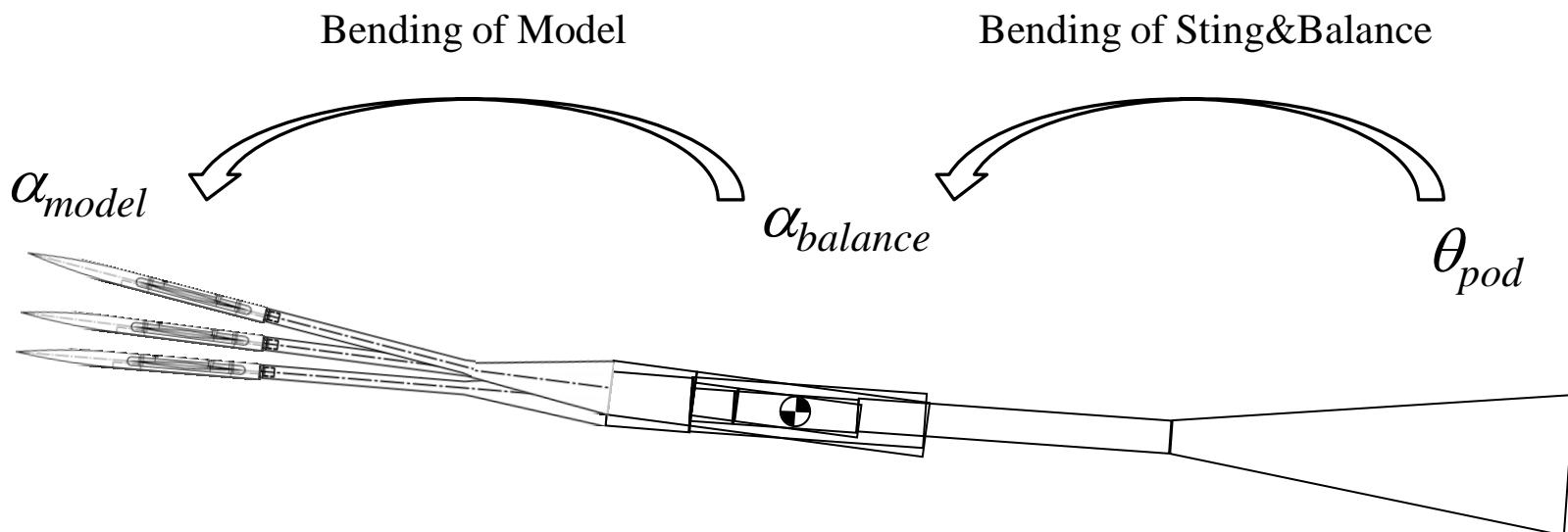
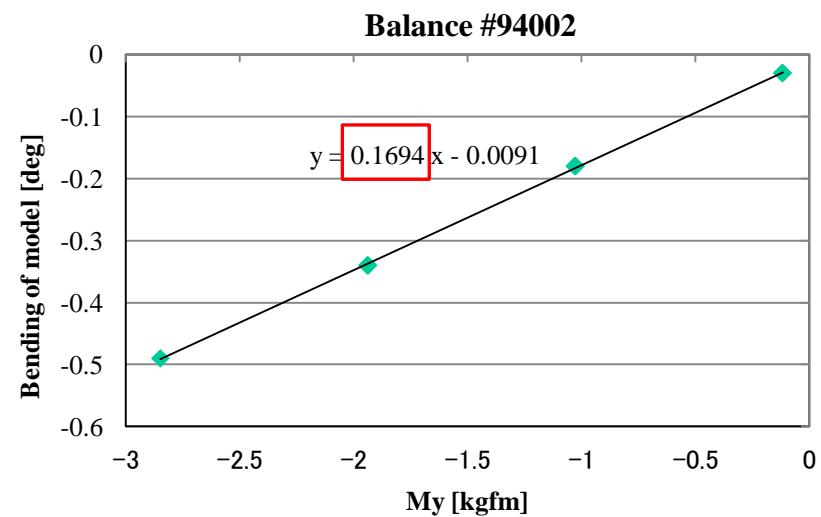
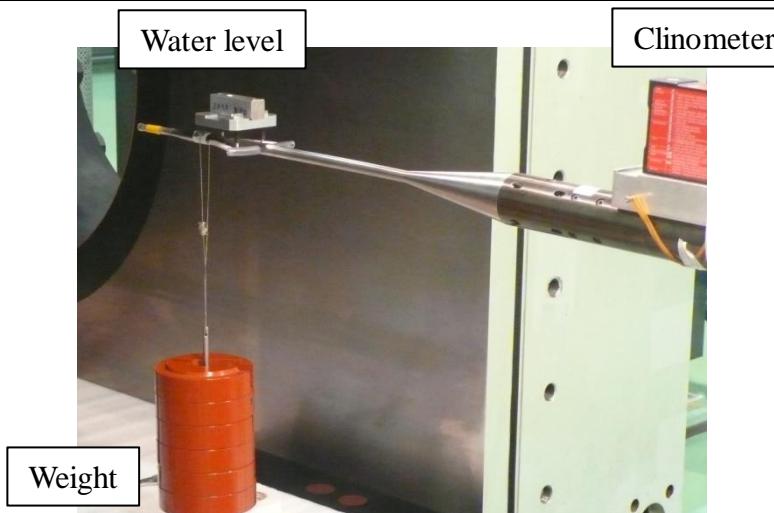
Mach Number Distribution



Mach Number Distribution

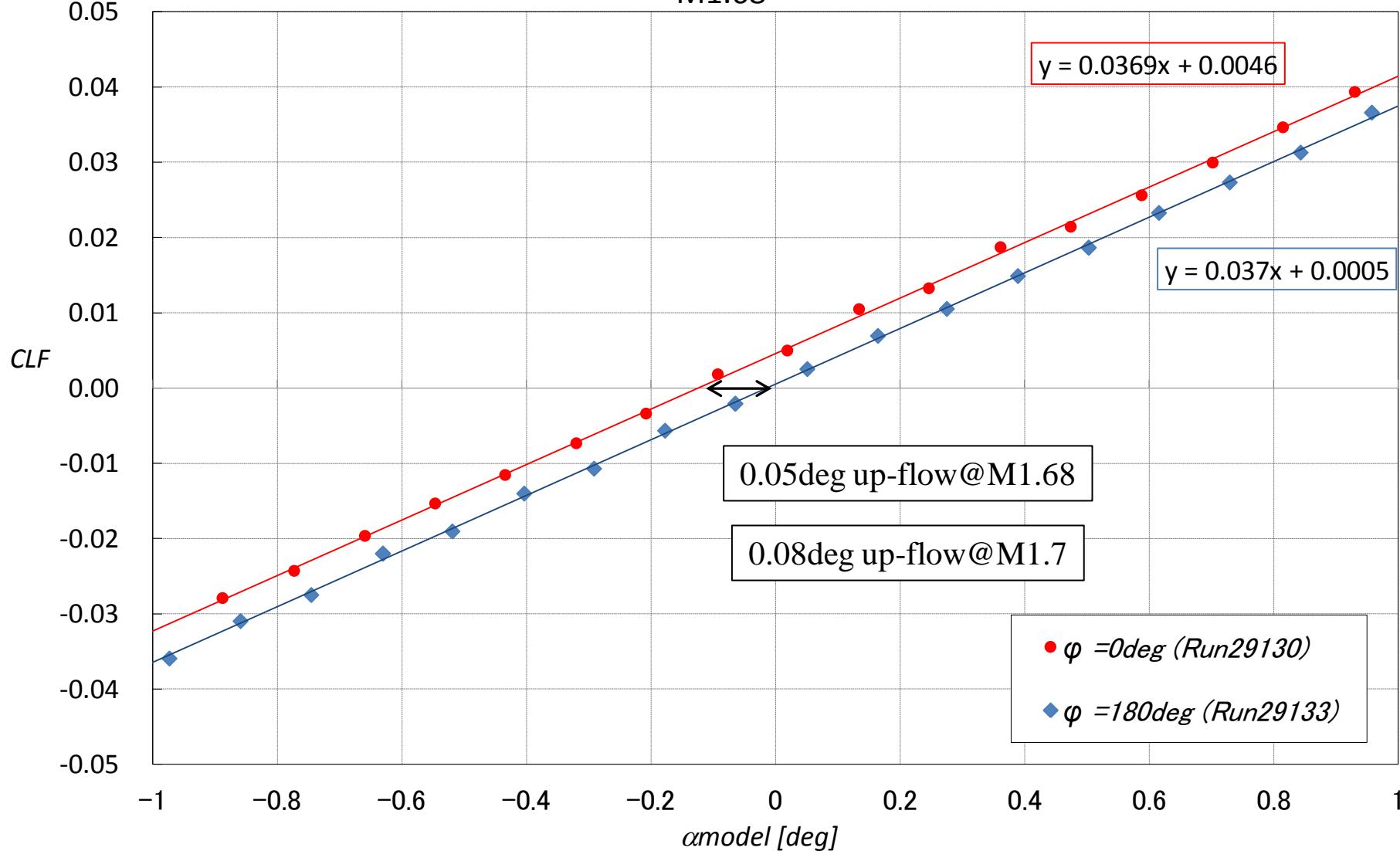


Model AoA Estimation

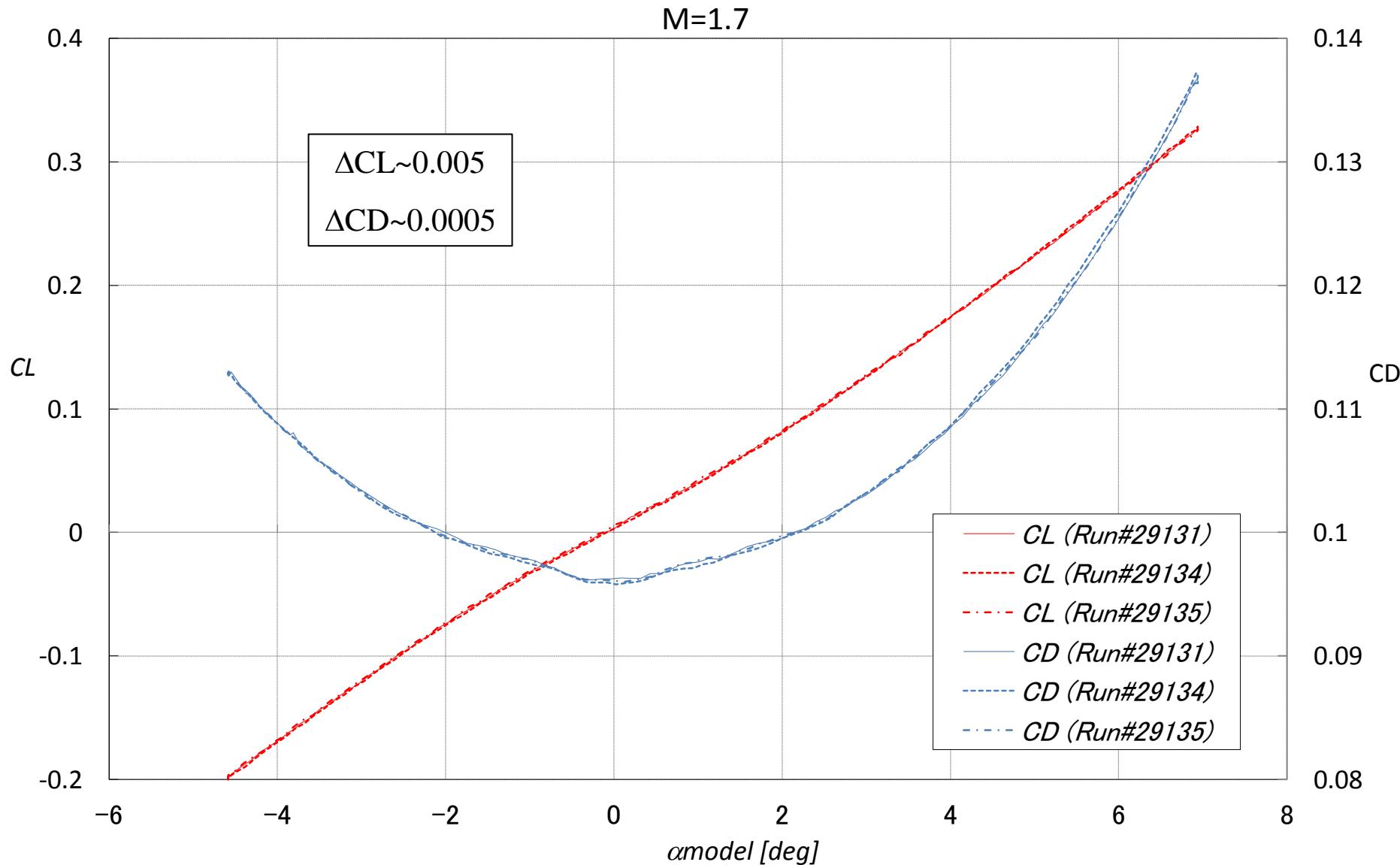


Up-flow/Down-flow

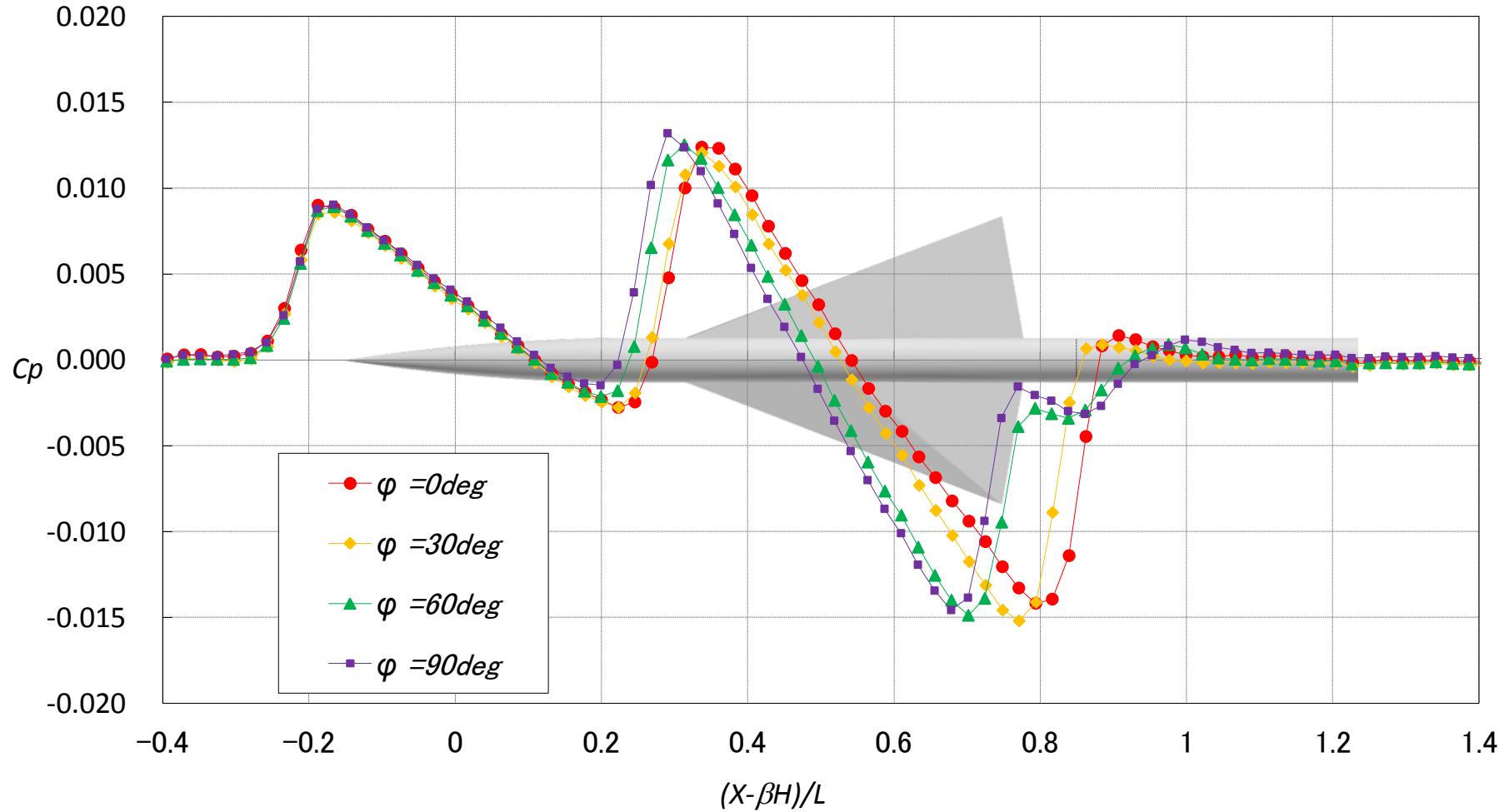
M1.68



Repeatability

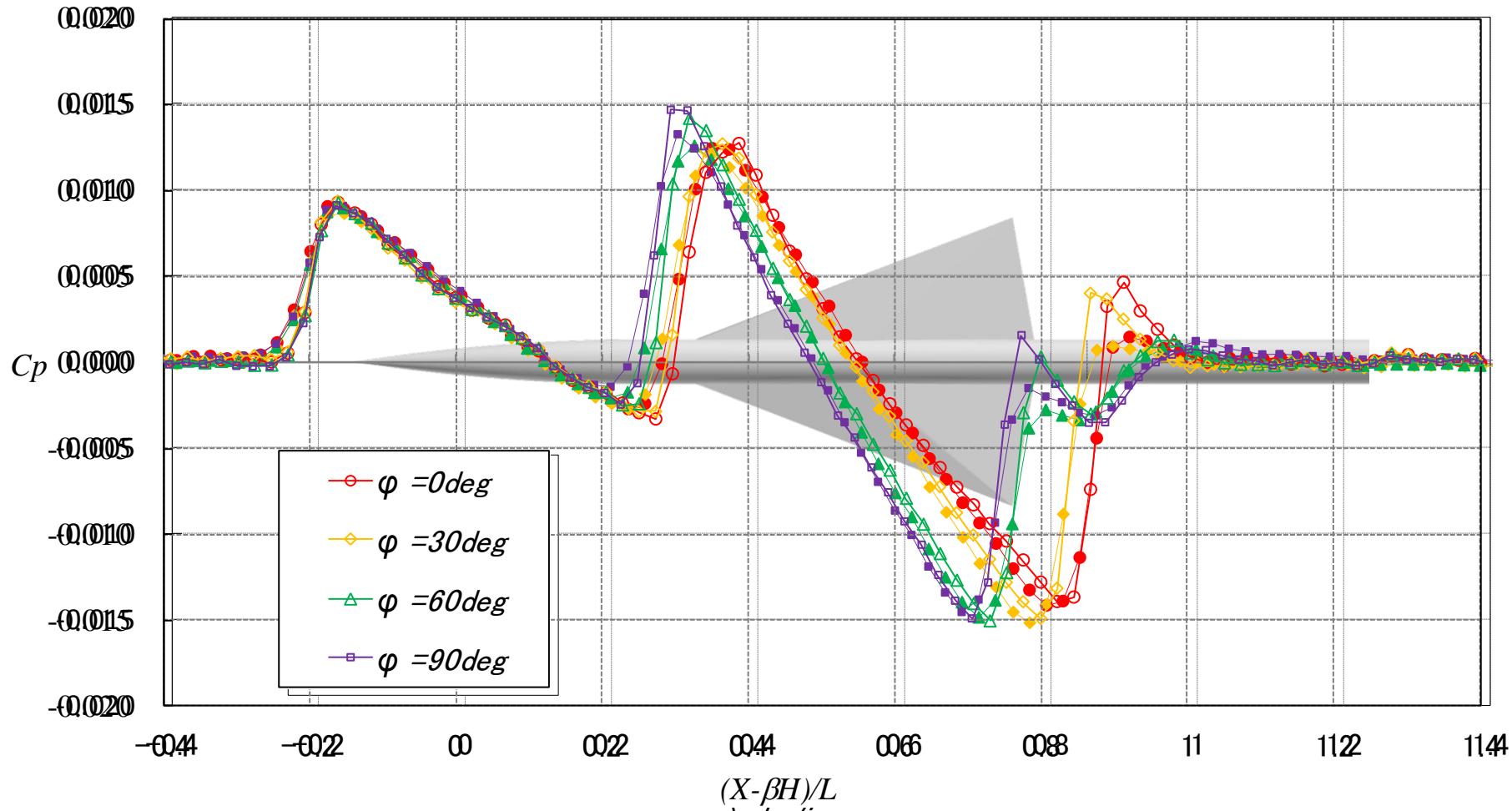


Near-field Pressure Signature for ϕ



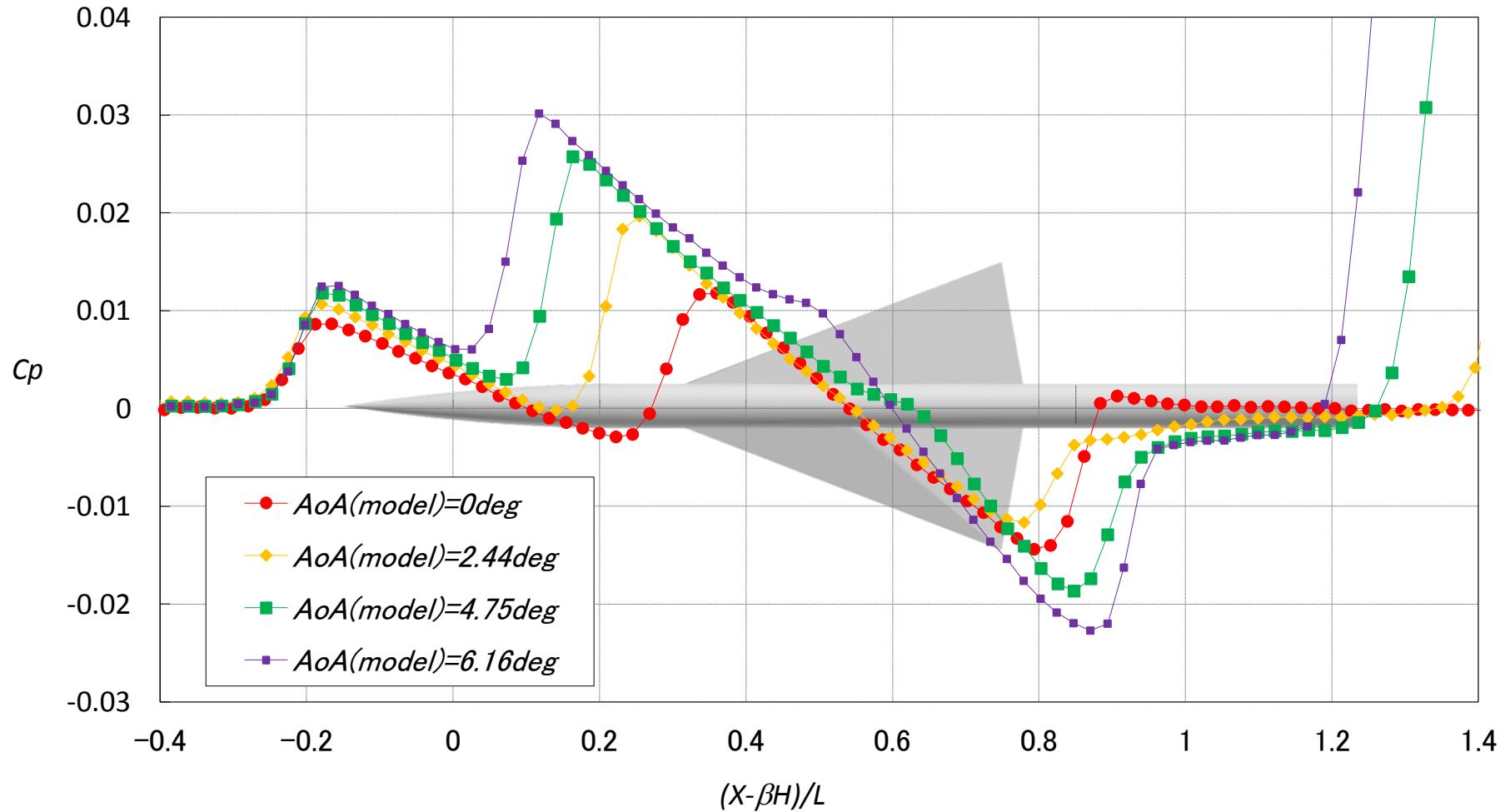
$M=1.68, \alpha=0\text{deg}, H/L=3.6, H_{rail}=0\text{mm}$

Comparison between $H_{rail}=0\text{mm}$ and 12mm



$M=1.68, \alpha=0\text{deg}, H/L=3.6, H_{rail}=0\text{mm}$

Near-field Pressure Signature for α



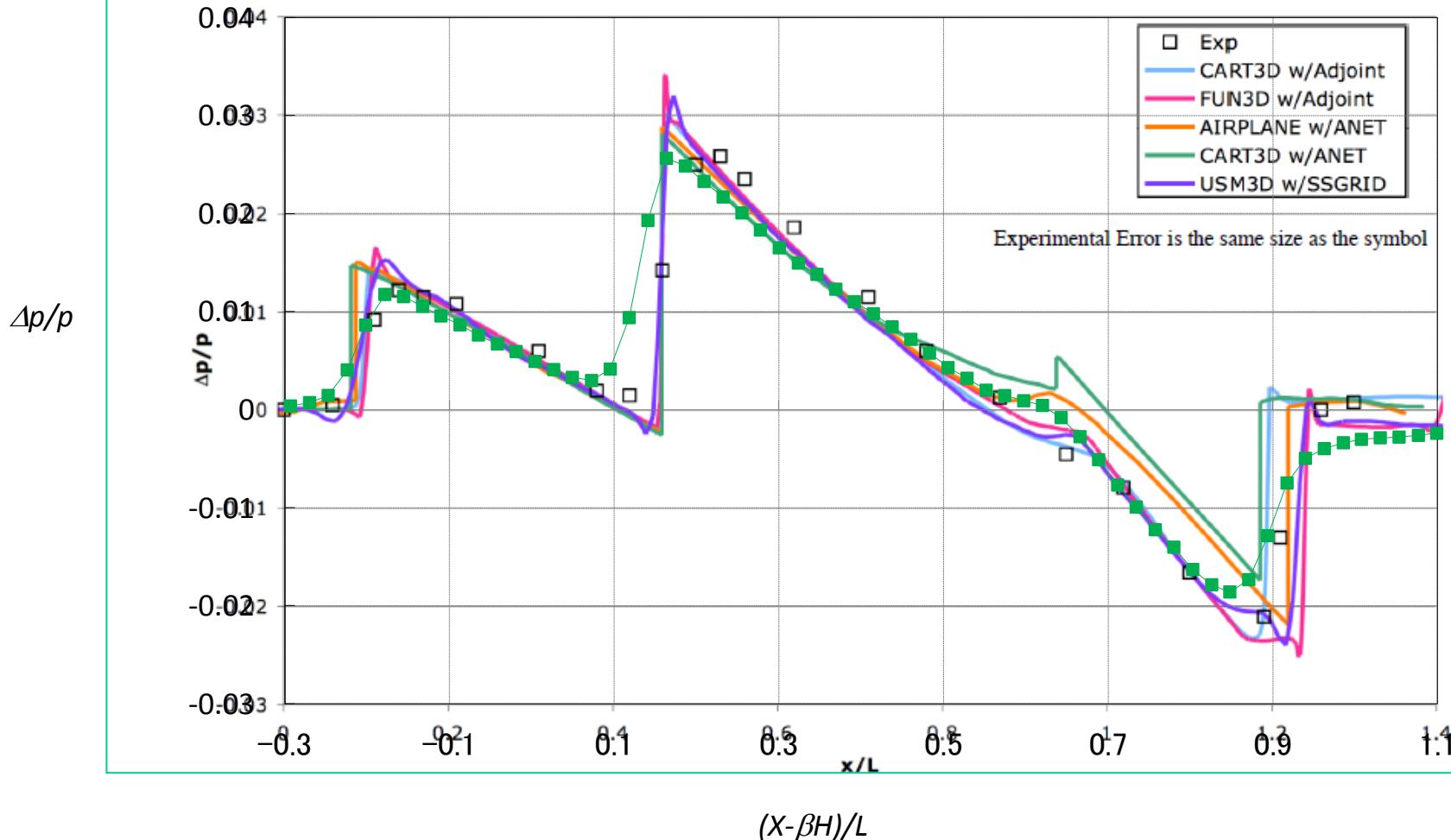
$M=1.68, \phi=0deg, H/L=3.6, H_{rail}=0mm$

Comparison with Old NASA Data

National Aeronautics and Space Administration



69-degree Swept Delta-Wing-Body - 3.6 BL



Summary

Near-field pressure signatures of several simple models are measured at JAXA's 1m x 1m supersonic wind tunnel(JSWT).

- The pressure measurement accuracy at JSWT using the pressure rail is within 0.0005 in C_p at about $M=1.7$.
- The model on/off correction works.
- The shock/boundary layer interaction dampens the measured pressure peaks when the rail height is low.
- The shock/rail interaction distorts the pressure signatures when the rail height is high.
- The near-field pressure signatures of the 69-degree delta wing body model are obtained for qualitative tool validation. (without shock/rail interaction effects)

Thank you !

